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OCULAR ABSORPTION OF LASER RADIATION FOR CALCULATING PERSONNEL HAZARDS

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The transmissions of ultraviolet, visible, and infrared radiation by the cornea, lens, and aqueous humor of rhesus monkeys were measured with spectrophotometers and from this the absorption coefficients were calculated over the spectral range from 200 nanometers in the ultraviolet through 15 micrometers in the infrared. Similar transmission data from previous studies on both human and rhesus monkey eyes were also converted to absorption coefficients.

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This final report was submitted by The University of Michigan, Ann Arbor, Michigan, under contract F41609-74-C-0008, job order number 6301-00-47, with the USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas. First Lieutenant Edward F. Maher, RAL, was the laboratory project scientist-in-charge.

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The animals involved in this study were procured, maintained, and used in accordance with the Animal Welfare Act of 1970 and the "Guide for the Care and Use of Laboratory Animals" prepared by the Institute of Laboratory Animal Resources - National Research Council.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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OCULAR ABSORPTION OF LASER RADIATION FOR CALCULATING PERSONNEL HAZARDS

Determination of the absorption coefficients in the ultraviolet and infrared of the ocular media of the rhesus monkey.

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INTRODUCTION

Objectives: The objective of this study has been to measure absorption coefficients of the cornea, aqueous and lens in the ultraviolet and infrared regions using narrow band-width radiation. Present and proposed operational lasers operate at many different wavelengths for which narrow band ocular absorption coefficients are not available, specifically in the ultraviolet and infrared. These ocular absorption coefficients are essential to develop a comprehensive mathematical model of ocular damage from lasers. The generation of a reliable model will significantly reduce the experimental program necessary to establish safe exposure levels.

The ocular absorption coefficients were to be obtained on rhesus monkeys for several reasons. First, previous experiences in this area showed the difficulties of obtaining sufficient normal human specimens for making such measurements. Second, previous work indicated that the similarity between the eyes of monkeys and humans was close enough so that good approximations can be obtained by making a size correction in moving from one species to the other. Third, because the monkey is frequently used to establish the degree of ocular damage from electromagnetic radiation, one can use such data along with the ocular measurements to evaluate the accuracy of any mathematical model.

Scope of the Problem: The contract required that measurements be made of the ocular transmission of the cornea, aqueous humor, and the lens of the rhesus monkey through the wavelength region of 200 to 400 nanometers in the ultraviolet and from 1.4 to 15 micrometers in the infrared. The measurements were to be made continuously with wavelength if technically possible, at narrow bandwidths not to exceed 0.2 nm in the ultraviolet and 0.045 μm in the infrared. The transmission measurements were to be converted into absorption coefficients except in those regions where the transmission was measured as less than one percent. We finally decreased this lower limit to <0.2%. In addition, we agreed in our response to the re-

quest for a proposal and in subsequent conferences that the measurements would include both direct and total transmission as defined in our previous work (1, 2, 3)* and would be extended to the wavelength region from 400 nm to 1.4 μm to statistically verify or improve our previous data. Also, we would convert our previous data on both monkey and human eyes into absorbance and absorption coefficients so that such information is available from 200 nm in the ultraviolet to 15 μm in the infrared. These conversions were to be made at close intervals and we finally selected 10 nm, except in the ultraviolet where the transmissions were changing rapidly and 5 nm intervals were converted.

Background and Literature Review: Many investigators have concerned themselves with the transmission and absorption of the ocular media to electromagnetic radiation, but almost entirely in the visible region to assist in studies about the physiology of the eye. One of the first investigators to concern himself with the transmission of the eye was Brucke, who investigated the reason for the invisibility of ultraviolet rays. Later, others investigated the visible and infrared portions of the spectrum. Duke-Elder summarized the work in this field up to 1952 very thoroughly in both Volumes 1 and 4 of his textbook (6). In this summary, most of the measurements reported have been made on animal eyes, especially those of the rabbit (13) and steer (10). The human data was that reported by Ludvigh and McCarthy (8) in 1938, giving measurements in the visible region of 4 human eyes of average age 62 years, all with sarcoma of the choroid. Geeraets and co-workers (7) measured 7 eyes, only 2 of which could be termed normal.

Because of the dearth of transmission information on human eyes, we began a research program in 1960 and continued until 1967, the aim of which was to determine the transmission characteristics of the eye *in vitro* for electromagnetic radation in the ultraviolet, visible, and infrared region.

*See page 22 for a list of references.

The program was divided into three phases. The first phase was to determine the transmission of the individual ocular media, i.e., cornea, aqueous humor, lens, and vitreous humor. Phase two was devoted to measuring the transmission of the composite ocular media, and phase three was concerned with measuring the transmission of the components of the fundus and the reflection from the fundus. The measurements were made on 16 enucleated human eyes and on numerous eyes of rhesus monkeys. This work culminated in our report of 1967 (3). Since that time, only a few papers concerning measurements in limited portions of the visible spectrum have been reported, with three devoted to measurements on the lens (4, 5, 9). An excellent review of the status of studies on human ocular absorption was compiled and published in 1972 by Dirk v. Norren of the Institute for Perception, in The Netherlands (11, 12). We have recently carried out a literature search for the period since 1972, but found no evidence of further work in this area.

EXPERIMENTAL PROCEDURE

Specimens: All measurements were made on the ocular media of (macaca mulatta) rhesus monkeys. The animals varied in weight from 4 to 10 kg, and were obtained and maintained by the University of Michigan Laboratory for Animal Medicine. This laboratory is accredited as an Animal Care Facility and all animals are handled in accordance with the procedures outlined in "Guide for Laboratory Animal Facilities and Care", U.S. Department of Health, Education and Welfare, N.I.H., and USAFSAM Regulation 169-2, July, 1972. Because of the cost and scarcity of rhesus monkeys, most animals were shared with other researchers, and sacrifice dates were coordinated to obtain a maximum utilization of each animal. Care was taken to assure that other experimenters used no drugs that would result in the ocular media being other than normal.

The operational protocol that was used was as follows: The Pathology Room of the Laboratory for Animal Medicine, which is about a city block from our laboratory, was scheduled for a particular time. After we arrived, an anesthetized monkey of a size we had specified was brought in and placed on an autopsy table. It was then given a sufficient dose of Eutonyl to kill it. The eyes were enucleated immediately after death, and the further dissection carried out immediately in the same room. The aqueous was first removed with a hypodermic syringe, introducing the needle in through the corneaoscleral limbus. The cornea was then removed by cutting around the edge with an iris scissors. It was immediately placed on one of the cell windows, covered with the other window, and placed in the holder. The lens was removed by clamping on the zonule with a tweezers and withdrawing the lens from the vitreous humor. It was placed in its cell, being retained in position by a plastic shim that centered it in the cell window. Another window covered it, compressing the lens slightly to decrease its optical power. Following this, the needle of the syringe containing the aqueous humor was introduced through the edge of a cell previously assembled for this purpose. The cells were moved to the var-

ious spectrophotometers and the measurements made in the shortest time possible. The first measurements were started within 40 to 60 minutes after the removal of the eye, with the subsequent measuring time varying from 20 to 120 minutes. A series of direct transmission measurements were made on the cornea, aqueous, and lens to determine any time effects after the specimens were sealed in the cells. Transmissions were measured at one, three, and seven hours after enucleation with the only effect being a slight increase in the transmission of the cornea (about 1% an hour). This agrees with our findings in the previous study, that showed a similar result.

Design of the Cells: The cells that were used to contain the ocular media were designed to permit their use in any of three ultraviolet spectrophotometers and two infrared spectrophotometers. A schematic drawing of the cell design is shown in Figure 1. Separate cells were utilized for the cornea, aqueous media, and lens. Likewise, a compensating cell was used in each measurement containing a single window equal in thickness to that of the two windows in the sample cell, thereby compensating for the reflection losses at the air-window interface and any absorption within the windows.

Two types of windows were used with the cells. For the ultraviolet region, synthetic fused quartz manufactured by Amersil, Inc., with the trade name Suprasil I was used. Windows 25 mm diameter and 1 mm thick were in the sample cells and one of the same size but 2 mm thick was in the compensating cell. The absorption of this material in the region from 200 to 500 nm is shown in Figure 2. For the infrared region, windows of zinc sulfide were obtained from Eastman Kodak Company. This material (trade name Irtran II) is water insoluble, has good transmission out to 12 μm, and is usable to 14.5 μm. Figure 3 shows the transmission of three windows 1 mm thick and one 2 mm thick. The three 1 mm windows (top curves) were measured because of their somewhat different coloring in visible light. However, as can be seen from the figure, their transmissions are within 1%, and the very small differences noted are not

correlated to the visible color differences. For the cell containing the cornea, a centering shim of 0.2 mm thick black plastic was used. For the lens, a similar shim 2.8 mm thick was used. The aqueous was held in a lead shim of 1 mm thickness, containing a small fill-hole through one edge. We also obtained one set of zinc selenide windows (Irtran 4) for measurements in the region from 12 to 15 μm, but they were used only to verify that the transmission in this region was less than 0.2%.

Measuring Instrumentation: Two types of measurements were made on the ocular media, defined in the same manner as in our previous work. The first was the measurement of Direct Transmission, which is defined as primarily that portion of the radiation that contributes to the image formed on the retina. The second was the measurement of Total Transmission, which includes both that radiation measured as direct transmission and that portion which is forward scattered by the ocular media. For the direct transmission measurements, four instruments were used, i.e., a Beckman DK-2A Recording Spectrophotometer, a Beckman Acta III, a Perkin-Elmer 221 Infrared Spectrophotometer and a Beckman IR-8 Infrared Spectrophotometer. In these instruments, the radiation beam is some distance from the detector, and is converging to a minimum size where it passes through the sample and strikes the entrance slit (in the infrared spectrophotometers) or proceeds to other optical elements that focus the radiation onto the detector (in the ultraviolet-visible instruments). Therefore, if any scattering media exist in a sample, that portion of the radiation that is scattered away from the defined beam and is not recorded by the detector, thereby reducing the measured transmission. For the total transmission measurements, an Aminco DW-2 Spectrophotometer and an interference filter photometer were used. In these instruments, the sample cells are immediately adjacent to a scatter plate and the detector. As a result, the radiation that passes through the sample illuminates the scatter plate, even if the sample scatters it as much as ±60° or more from its original path.

Beckman DK-2A Recording Spectrophotometer: This instrument disperses

the radiation with a quartz prism in a littrow arrangement, and has adjustable slits, with the slit width controlled either manually or by a servo mechanism (Figure 4). Its wavelength range is from 185 nm to 3500 nm. The spectral bandwidth is variable depending on the wavelength and slit width, and the manufacturer gives dispersion curves (Figure 5) for determining the bandwidth. Using these curves, the data in Table I were obtained. To check the bandwidths experimentally, a mercury discharge tube was used as a line source, and the measured spectral bandwidth was determined at 253.7 nm for several slit widths. These values are compared in Table II with the manufacturer's claims (obtained from Figure 5). This indicates that the measured values on our instrument is 30 to 40% greater than those obtained from Figure 5. The wavelength accuracy of this instrument is within specs, and is better than ±0.5 nm.

Beckman Acta: This is a recording spectrophotometer for the spectral region from 190 to 800 nm. It has adjustable slits and disperses the radiation with a single grating (Figure 6). Its dispersion varies slightly with wavelength (Figure 7) because of the optical design. Table III gives the measured slit width and dispersion using the tungsten source from 350 to 800 nm and the deuterium source from 200 to 350 nm. The bandwidth was determined from Figure 7, using the measured slit widths. These values all are within the "less than 0.2nm" specification for the instrument, except at wavelengths greater than 700 nm, where the decreasing sensitivity of the phototube requires wide slit widths. Using holmium oxide glass as a wavelength standard, we confirmed the wavelength accuracy as being better than ±0.5 nm.

Perkin-Elmer 221 Infrared Spectrophotometer: This instrument records the absorption spectrum from 1 to 15 μm using a sodium chloride prism. It uses the prism in a littrow arrangement (Figure 8), with its dispersion increasing with wavelength. However, if one uses the automatic slit program incorporated in the instrument, the slit widths increase at a somewhat equal rate, resulting in a band width that remains within a factor of two out to 13 μm. Table IV gives the effective band-

width on the basis of the manufacturer's specification at 12.5 μm and measurement of slit width when using the slit programming. We used somewhat narrower slit widths at wavelengths greater than 10 μm to gain better resolution in this region.

Beckman IR-8 Infrared Spectrophotometer: This instrument will record the spectrum from 2.5 to 16 μm using two diffraction gratings. From 2.5 to 5 μm, a grating having 300 lines per mm is used, and a second grating having 100 lines per mm is used for the balance of the spectral region. The instrument has fairly uniform dispersion typical of a grating instrument. The optical design is shown in Figure 9. The bandwidths, based on the manufacturer's dispersion curves, are reported in Table V.

Aminco DW-2 Spectrophotometer: This instrument was selected because of its ability to measure the transmission of turbid solutions, and therefore is ideal for measuring what we have termed total transmission. This is made possible by using a large end-on photomultiplier tube as the detector, and placing the cell and a scatter plate almost against the photocathode. In doing this, one is measuring the total transmission over the most of a hemisphere, accomplishing the same thing as we did in our previous work by using an integrating sphere arrangement. The DW-2 uses a modified Czerny-Turner grating monochrometer, with slits whose spectral bandpass is continuously adjustable from 0 to 17 nm. The optical arrangement is shown schematically in Figure 10. On our instrument, the usable wavelength range is from 200 to 825 nm, with the manufacturer's claiming a resolution of "better than 3 Å determined by the mercury triplet at 365 nm".

Filter Photometer: A filter photometer for measuring the total transmission at several discrete wavelengths in the infrared was assembled. A schematic diagram of the optical arrangement is shown in Figure 11. The infrared source is a coiled section of Chromel No. 23 heating wire heated electrically to about 800°C. The cells that hold the ocular media being measured are the same cells as used in the spectrophotometric measurements.

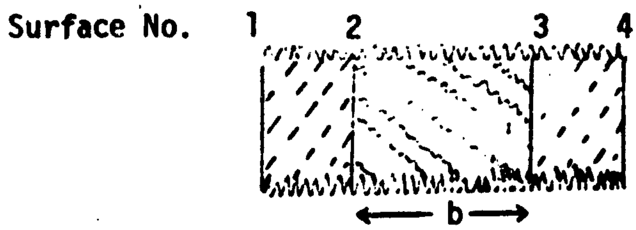
The scatter plate is a sodium chloride window with one roughly ground surface. Interference filters for measurements at 1.075, 1.55, 2.14, 3.6, and 5.5 μm were used. Operationally, one measures the ratio of the radiation through the cell (both with and without a sample) to that without the cell in place, thereby obtain the transmission of the particular component being measured.

The infrared photometer would be relatively insensitive for measurements in the ultraviolet, and because two types of lasers (Nd at 265 nm and N_2 at 337 nm) can generate relatively high powers in this region, it was decided to also assemble an ultraviolet filter photometer. This instrumental arrangement used is shown in Figure 12. The detector in this device is a R.C.A. 1P28 photomultier tube with an ultraviolet transmitting envelope for good sensitivity from 200 to 650 nm. We have two filters on hand for this region (260 and 335 nm). Measurements are made in the same way as described for the infrared filter photometer.

Transmission Measurements: Sometime prior to measuring the ocular media, the various spectrophotometers were warmed up and the 100% transmission line established. Then the individual cells with their diaphragm in place (but no ocular media) were also run to establish their transmission. This is necessary for those cases where the cell aperture is smaller than the beam of radiant energy passing through the sample. Correction of the transmission for the reflection loss at the outer surfaces of the cell windows and for absorption by these windows was handled continuously during recording by having a single double-thickness window in the reference beam. After the specimens were placed in the cells, the measurements were begun, usually within about 45 minutes after the eyes were enculeated. The 100% transmission line was checked for any drift before and after each run. Transmission measurements were made for the entire region from 200 nm to 15 μm. However, these measurements were not converted into absorbance or absorption coefficients in those regions where the transmission was less than 0.2%, because of the uncertainty of the measurements below this value.

Data Conversion Mathematics: A computer program was developed to make use of the IBM 360 computer at the University's Computing Center, in order to convert the large amount of data to be generated as percent transmission into absorbance and absorption coefficients. To establish the spectral absorption of any material, it is necessary to measure the transmission and either electronically convert it to absorbance using logarithmic amplification or subsequently compute the absorbance. Further computation is necessary to correct for reflection losses and to convert the data into either absorption coefficient or absorptivity at the wavelengths of interest. Therefore, it appeared desirable to develop a computer program to carry out the many computations. The programs which perform these types of computations are very elementary once the problem is defined, so this was our starting point.

The problem: What is the decrease in radiant energy of wavelength A in passing through an absorbing medium of thickness b contained between two windows as described in the sketch below?



Assume that the reflection losses off of the air-window interfaces 1 and 4 and any absorption by the windows are cancelled out by putting in the reference beam of the spectrophotometer a single window of the same material and of thickness equal to that of the two cell windows. Then, at surface 2, if the incident intensity is I_o, let the transmitted intensity be I_{2t} and from Fresnel's reflection law:

$$I_{2t} = I_o - I_o\left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

The incident intensity at surface 3 (after being absorbed by the media) is

$I_{3i} = I_{2t} \cdot 10^{-ab}$ where a is the absorptivity. The transmitted intensity at surface 3 is

$$I_{3t} = I_{3i} - I_{3i}\left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

then

$$I_{3t} = I = \left(I_{2t} \cdot 10^{-ab}\right)\left[1 - \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right]$$

$$= \left[I_o - I_o\left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right] 10^{-ab} \left[1 - \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right]$$

or

$$\log \frac{I_o}{I}\left[1 - \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right]^2 = ab = A, \text{ where A is absorbance}$$

If one wants the absorption coefficient

$$\alpha b = \ln \frac{I_o}{I}\left[1 - \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right]^2$$

The procedure that was followed to generate the data required of this research was to measure spectrophotometrically the transmission of the ocular media at various wavelengths. These measurements were in percent transmissions and were uncorrected for internal reflection losses. As such, the transmissions (%T) were equal to $\frac{100\ I}{I_o}$ in the above formulae. So the first requirement was to correct for the reflection loss, or

$$\%T_{(corr)} = \frac{100\ I}{I_o}\left[1 - \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2\right]^{-2}$$

then one could determine α, a, and A using the following relations:

$$\alpha = \ln \frac{100}{\%T\ (corr)}\ /b$$

$$a = \log \frac{100}{\%T(corr)}\ /b$$

$$A = a\ b$$

In our first program we used a single value of n_2, the index of refraction

of ocular media at a single wavelength in the visible, to correct for reflection losses at all wavelengths. This was done because the only published indices of refraction are one or two values in the visible. Inasmuch as these data are close to those for water at the same wavelength, we felt that a better correction would be obtained by using the indices of water at all wavelengths, as they are available throughout the spectral regions of interest. The Fortran statements to do this, along with a printout of the modified program, are given in Appendix III. A comparison of the results from the two programs showed that this refinement resulted in only a very small change in the final data, with the greatest change in the infrared when using the Irtran II windows.

Data Handling: After the spectra were recorded on each animal, corrections were made in the transmission for any shift in the 100% transmission line and for any reduction in transmission due to the cell diaphragm. These values were placed on punch cards, along with the wavelengths. With each card set was retained data on the weight of the animal, the diameter at the geometrical equator of the eye, the date, and instrument used. The computer had been programmed (see Appendix III) to do the following at each wavelength:

1. Adjust the % transmission reading to correct for reflection losses between the cell windows and the monkey ocular media.
2. Change the adjusted % transmission reading from step 1 into absorbance $\left(A = \log_{10} \frac{100}{\%T}\right)$.
3. Calculate the absorptivity ($a = A/b$, where b is the thickness in cm).
4. Calculate the Lambert absorption coefficient for monkey ocular media ($\alpha = a/.434$).
5. Calculate the absorbance of the human ocular media ($A = ab$).
6. Calculate the % transmission of the human ocular media.

The data from step 1 were plotted into an absorption spectrum to produce a composite curve for each ocular medium. From these a master curve was

developed that represents the best fit of the better spectra. Transmission data was transferred from the master spectrum to punched cards at closely spaced wavelength intervals (depending on the rate of change of transmission at that wavelength) and the computations in step 2 through 6 were carried out.

To calculate the absorption coefficients (step 3) one must apply the length of the absorption path. In the case of the aqueous and the lens, this was determined by the thickness of the shims used in the cells, which were 1 mm and 2.8 mm respectively in these cases. For the cornea, the absorbing thickness was determined by the cornea itself. Because attempts to measure the average thickness of the cornea, either directly or microscopically, were only partially successful (see page 16, Discussion of Results) we decided to use the average thickness of the living human cornea (0.6 mm), as reported by Duke-Elder (6) and proportionally reduce this by the ratio of the diameter of the human eye to the measured diameter of each monkey eye. This resulted in an average monkey corneal thickness of 0.515 mm. To calculate the absorbance and % transmission of human ocular media (step 5 and 6) path lengths of 0.60 mm, 3.0 mm, and 3.2 mm were used for the cornea, aqueous, and lens respectively.

RESULTS

Transmissions of the ocular media of 23 male rhesus monkeys (macaca mulatta) were measured in this program. The animals varied in weight from 4 to 10 kg, and, according to the veterinarians in our Animal Care Center, probably ranged in age from 2 1/2 to 8 years.

The transmission measurements were compiled into composite curves for each ocular medium and best fit or master curves were developed according to criteria stated in the section "Discussion of Results". The master transmission curves are reproduced in Figures 13 through 18. Although the transmission was measured from 200 nm in the ultraviolet to 15 μm in the infrared, the curves as reproduced were terminated at 2.6 μm in the infrared as no transmission greater than 0.2% was observed beyond this point. Also in these figures is a plot of the log of the absorption coefficient. The data taken from these transmission curves is repeated in the computer print-out shown in Tables X through XIV of Appendix IV. These tables also contain the values of absorbance (A), absorption coefficient (α) and, absorptivity (a) of the monkey eye and the corresponding absorbance and transmission of the human eye as calculated from the monkey data. The data in the tables are tabulated from the shortest wavelength where the percent transmission is at least 0.2% to the longest wavelength showing a similar transmission. This figure of 0.2% is a conservative estimate of the smallest amount of transmission to which our instruments will respond.

Other Physical Measurements: In conjunction with our measuring program, we accumulated a small amount of information on the size of the entire eye of the rhesus monkey and the water content of the cornea and lens. The diameter of the eye, measured at the geometrical equator using a vernier caliper, varied from 19.6 to 21.5 mm, with most being 20.8 ± 0.2 mm. Although the weights of the animals varied from 4 to 10 kg, there seemed to be no correlation between the weights and eye diameters. This is perhaps not surprising, inasmuch as the diameter of the human

eye does not change drastically with age.

The water content of the cornea and lens was of interest because of the high absorption by water in the infrared region of the spectrum. We determined the amount of water by weighing and drying after completing the transmission measurements. The weighing was done on an analytical balance before and after drying the specimens in a laboratory drying oven at 110°C for five hours. The water content of the cornea was 81 ± 3% by weight and that of the lens was found to be 71 ± 3% by weight.

DISCUSSION OF RESULTS

As stated in the RESULTS section, the transmissions as obtained from each spectrophotometer record were compiled into composite curves, from which a master curve was developed by selecting what was considered the most representative transmission reading at each wavelength. In making this selection a number of factors had to be considered as to causes for the spread in the data.

1. In good spectrophotometry on clear solutions, variations in transmission measurements may be less than 1%, but on biological specimens containing small amounts of particulate matter (aqueous) or containing inhomogeneities in structure (cornea, lens), the precision on measurements deteriorate, due to the scattering of a portion of the radiation. The effect of this scattering will vary with the spectrophotometer design and its optical alignment.
2. The amount of scattering will vary with the "cleanliness" of the specimen, i.e., was it contaminated with blood that one encounters in the enucleation and dissection? Likewise, were the cell windows clean?
3. Finally, there is the spread in the data due to the difference in transmission from the ocular media of one monkey to another.

The instrumental differences were measured and reduced by measuring the transmission of partially scattering solids (translucent plascics, etc.) and optimizing optical alignments when necessary. Any transmission differences introduced by the instruments were generally considerably less than those introduced by factors 2 and 3.

Maintaining the cleanliness of the specimens was the major problem, compounded by the desire to maintain speed during the removal of the eye but especially the dissection. The principal contaminates appeared to be blood on the cornea, which was removed by washing with saline solution

before mounting in the cell, and contamination of the aqueous humor by small fragments of the iris. These contaminates always had the effect of lowering the transmissions.

Knowing how the above factors entered our individual runs, some data was discarded and a median was selected on the remainder. Table VI is a statistical summary of the data at several wavelengths. The spread of the remaining data is the total spread, after excluding some samples.

Cornea: The direct transmission readings (Figure 13 and 14), were obtained on three instruments, the DK-2A, the Acta II, and the P.E 221 (greater than 1.0 μm). In making the first few measurements we encountered a significant departure from our previous measurements when using the DK-2A, which was traced to the field of view of the measuring photometer part of the spectrophotometer. In the previous measurements, the viewing field was established as about 1°, based on manufacturer's data, and on tracing the matter, found our present DK-2A to be plus 0° and minus 3°, due to a misalignment of the optics. Realigning the instrument brought the field back almost to that used previously. The field of the Acta II is about 2.5° while that of the P.E. 221 is very close to 1°. To maintain a consistancy with our previous definition of direct transmission, all results were normalized to the 1° figure. The spread of the normalized data is indicated in Table VI. The samples excluded were in all cases the early measurements on the DK-2A before realignment.

The total transmission measurements (Figure 13 and 14), were obtained on the Aminco instrument in the ultraviolet and visible out to 800 nm. For the infrared, the filter photometer was used at three wavelengths, (1.075, 1.55, and 2.14 μm), and these values were correlated with the direct transmission measurement and our previous measurements to produce the total transmission curve. A discussion of measurement problems with the filter photometer at 1.55 μm is given in the subsection " Filter Photometer Measurements".

In calculating the absorption coefficient and absorptivity of the cornea the value of 0.515 mm was used as the thickness as stated on page 13. The reason for this was our inability to make a satisfactory measurement of the average thickness. We first attempted to measure the thickness microscopically, focusing the microscope on first one surface and then measuring the travel of the objective to focus on the second surface. The difficulty in selecting the exact focal plane and the depth of focus effect introduced errors as great as $\pm$ 0.1 mm. The direct measurement with a micrometer produces even greater variations because of the compressability of the cornea over small areas. The method closest to being acceptable was to measure the sandwich consisting of the cell windows and cornea, with the micrometer, and then subtracting the thickness of the windows. Even over the entire area of the cornea, the compressability was still a factor, so even here the variation in the measurement was $\pm$ 0.1 but averaged about 0.5 mm. We also measured this sandwith with the plastic shim in place, and found that although the shim was 0.2 mm thick it overlapped only a very small area on the edge of the cornea and compressed this portion so that the overall thickness of the cell appeared to increase less than 0.1 mm with the shim in place. Once again, this was hard to measure because of the compressability of the sandwich. We talked to colleagues in ophthalmology research concerning the possibility of using a slit lamp to make measurement of the corneal thickness, and they discouraged us because of the difficulties one encounters in calibrating the technique for absolute measurements.

Aqueous: The aqueous measurements (Figure 15 and 16) were made on the DK-2A, Acta, and Aminco. Because of the lack of scattering material in the aqueous, only a single set of data results. The data that was excluded (Table VI) was the result of the aqueous being contaminated with small amounts of iris pigment. This was readily evident from the transmission readings with the DK-2A or Acta.

Lens: These measurements were made primarily with the DK-2A and the Acta II. A statistical analysis of these data showed it to fall into two groups shown in Figure 17 and 18. The data in curve 2 is from a group of six lenses with a higher transmission and smaller deviations, and with close agreement to our previous work. The other group, curve 3, have lower transmission and a greater data spread, yet seem to be statistical significant as a group. The two groups do not correlate with the measuring spectrophotometers, in that data from both instruments are represented in both groups. Also, efforts to correlate the difference to the size of the animal or the date of the measurement were not successful. Questioning the veterinarian at the Animal Center as to whether there was a possibility of sub-speces differences, he indicated that to the best of his knowledge, these were all the macaca mulatta type of rhesus monkey, and were imported by a single importer from one area of India.

The total transmission measurements were made both with the Aminco instruments and the filter photometer. This data fell into a single group, unlike the direct transmission measurements previously described. The problem is using the filter photometer at 1.55 μm was also encountered here, and is described in the next section.

Filter Photometer Measurements: In making measurements with the filter photometer, we encountered two unanticipated measuring problems. The first was in the infrared region, where interference filters were ordered to correspond to five transmission maxima, i.e., 1.075, 1.65, 2.2, 3.8, and 5.4 μm. The filters as received and measured in our laboratory peaked at 1.075, 1.55, 2.14, 3.6 and 5.5 μm. These values were close enough to the desired values to cause no problems except the one at 1.55 μm, which peaks on the edge of an absorption band. The first two attempts to use this gave values greater than expected. In analyzing the discrepancy, it became apparent that in order to calculate and integrate the band-pass of the filter when using it to measure absorption in a rapidly changing region one also had to know the spectral distribution of the radiation

source (or its color temperature). This was determined in subsequent measurements but because of difficulties in obtaining precise temperature values, the end result of the measured total transmission at 1.55 μm was quite variable, as the standard deviations in Table VI indicate.

The other problem encountered was in the ultraviolet region, where a filter peaking at 260 nm was obtained, to observe the region corresponding to that of the output of a Nd-yag laser. In making filter photometer measurements at this wavelength on two corneas, we were surprized to obtain "transmissions" of 3.0 and 3.6% when according to much previous work, the measured total transmission should be less than 0.1%. On investigating, we found that the cornea fluoresces at 340 nm when excited with radiation having a wavelength of 260 nm, and it was this longer wavelength radiation that our photometer was measuring. This was determined by measurements on an Aminco-Bowman Spectrofluorometer. Subsequent measurements were also made on the aqueous and lens, which were also found to fluoresce. It was found that all three media emitted radiation from 330 to 355 nm when excited with radiation from 260 to 300 nm. In addition, the lens will emit from 445 to 460 nm when excited with radiation from 345 to 375 nm. The amounts of fluorescence were not quantified, and considerably more work will be necessary in order to quantitatively establish the spectral quantum yield of the fluorescence in the ocular media. However, it is doubtful that this fluoresce was sufficient to effect our total transmission readings on the ocular media at the short wavelengths because of the very low power levels of the exciting radiation incident on the cell in the conventional spectrophotometers.

Carbon Dioxide Laser Measurements: We were interested in obtaining some total transmission measurements of both water and the cornea using a CO_2 laser and thermocouple combination. The purpose of the test was to both determine that the narrow band pass of the laser at 10.6 μm resulted in the same very low transmission reading obtained with a spectrophotometer, and to determine whether this would be a practical technique

to determine the absorption coefficients of water in the highly absorbed regions of the spectrum.

Arrangements were made with the Environmental Research Institute of Michigan (ERIM) to use their CO_2 laser on three occasions, taking the cornea, sealed in its cell, to their laboratory for the measurements. The transmission of the cornea was measured as being less than 0.001% for this wavelength. We were unable to extend the measurements to lower values because of problems associated with calibrating the equipment over such a large range of attenuation ($>10^5$). Even in measuring the transmission of a thin layer (0.1 mm) of water at this wavelength, although our values were within an order of magnitude of the published values determined by reflection, the problems of calibrating the measuring system over this wide difference in radiation intensity between I and I_o are considerable. In Appendix II, it is suggested that this may be an approach to obtaining more precise measurements of the absorption coefficients of water in the highly absorbing regions. Our experiment in this regard shows that the measuring system may encounter calibrating problems that in the end could result in measurements with a variability as great as those obtained by the reflection method.

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Table I

Beckman DK-2A -- Calculated Bandwidths

WAVELENGTH	SENSITIVITY =MAX.		SENSITIVITY =20		SENSITIVITY =10	
nm	Slit Width	Band-Width	Slit Width	Band-Width	Slit Width	Band-Width
	mm	nm	mm	nm	mm	nm
200 -	.30	.235	.38	.293	.54	.408
205 -	.21	.187	.26	.227	.38	.323
210 -	.142	.147	.19	.191	.26	.255
250 -	.051	.092	.068	.122	.091	.164
300 -	.039	.159	.053	.212	.065	.258
350 -	.035	.311	.045	.374	.057	.449
400 -			.025	.493	.030	.541
500 -			.018	.910	.018	.91
600 -			.018	1.794	.022	1.93
700 -			.030	3.14	.0[illegible]2	3.72
800 -			.029	4.05	.[illegible]38	4.63

Table II

Resolution of Beckman DK-2A at 253.7 nm

Slit Width, nm	Measured Bandwidth, nm	Calculated Bandwidth, nm
.020	.076	.036
.060	.14	.108
.090	.21	.162
.15	.32	.27
.20	.44	.36
.30	.62	.54

Table III

Beckman Acta -- Calculated Bandwidths

Wavelength nm	Slit Width mm	Dispersion nm/mm	Bandwidth, nm (calculated)
200	.080	2.365	.189
205	.070	2.36	.165
210	.060	2.36	.165
250	.041	2.355	.096
300	.057	2.34	.133
350	.045	2.33	.015
400	.075	2.31	.17
500	.041	2.27	.093
600	.034	2.22	.075
700	.064	2.16	.138
800	.33	2.08	.6864

Table IV

Perkin-Elmer 221 Infrared Spectrophotometer

Calculated Bandwidths

λ	dn/dλ	Slit Width (mm)	Band-width (μm)
2.5	.0024	.02	.010
5.0	.003	.04	.014
7.5	.0044	.069	.016
10.	.0062	.11	.018
12.5	.0095	.185	.020
15.	.011	.54	.053

Table V

Beckman IR-8 Spectrophotometer

Calculated Bandwidths

λ	Slit Width (mm)	Band-width (μm)	Slit Width (mm)	Band-width (μm)
2.5	.3	.021		
5.0	.4	.028	.1	.011
7.5	.55	.035	.14	.015
10.	.8	.049	.2	.020
12.5	1.1	.061	.28	.024
15.	1.8	.080	.45	.029

Table VI

Statistical Data

	λ (nm)	Total Samples	Samples Excluded	Spread of Remainder	Standard Deviation
Table I	400	19	6	14%	5.4%
	800	31	13	13%	5.0%
	1075	26	13	12%	3.1%
	2200	24	8	12%	3.8%
Table II	400	8	1	11%	4.2%
	800	8	1	7%	2.6%
	1075	5		13%	5.6%
	1550	5		16%	7.0%
	2140	6		7%	3.0%
Table III	400	13	5	7%	2.3%
	800	12	3	9%	2.5%
	1075	9		7%	2.4%
	2200	9		4%	1.2%
Table IVa.	500	6		9%	2.9%
	800	6		6%	2.2%
	1075	5		9%	5.3%
	1660	5		5%	2.0%
Table IVb.	500	11	2	20%	7.3%
	800	17	1	29%	8.3%
	1075	13	3	13%	5.4%
	1660	13	1	7%	2.4%
Table V	500	8	1	9%	3.4%
	800	7		6%	2.0%
	1075	4		7%	4.4%
	1550	5	2	9%	5.5%

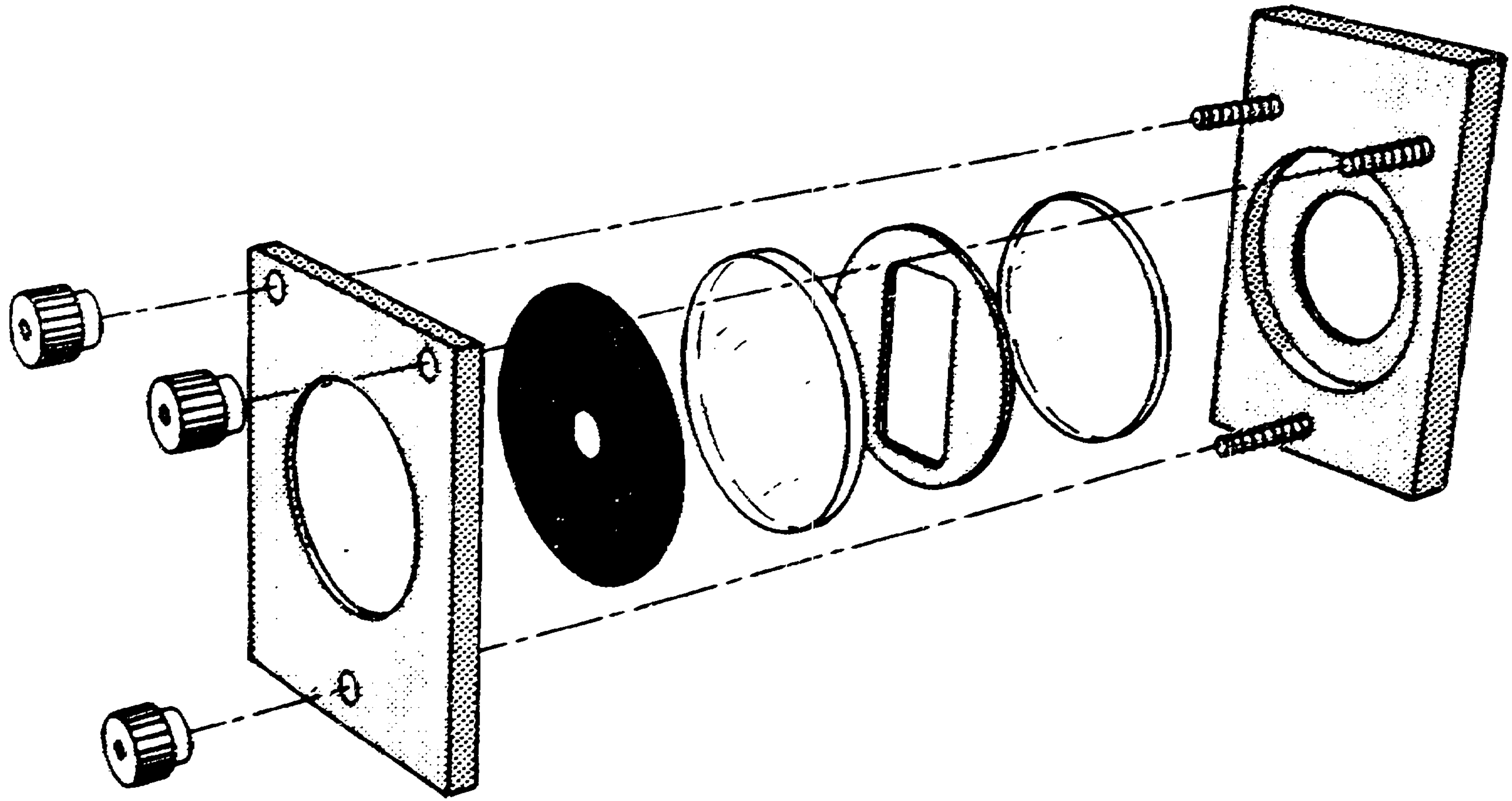


Figure 1: Schematic Design of Cell

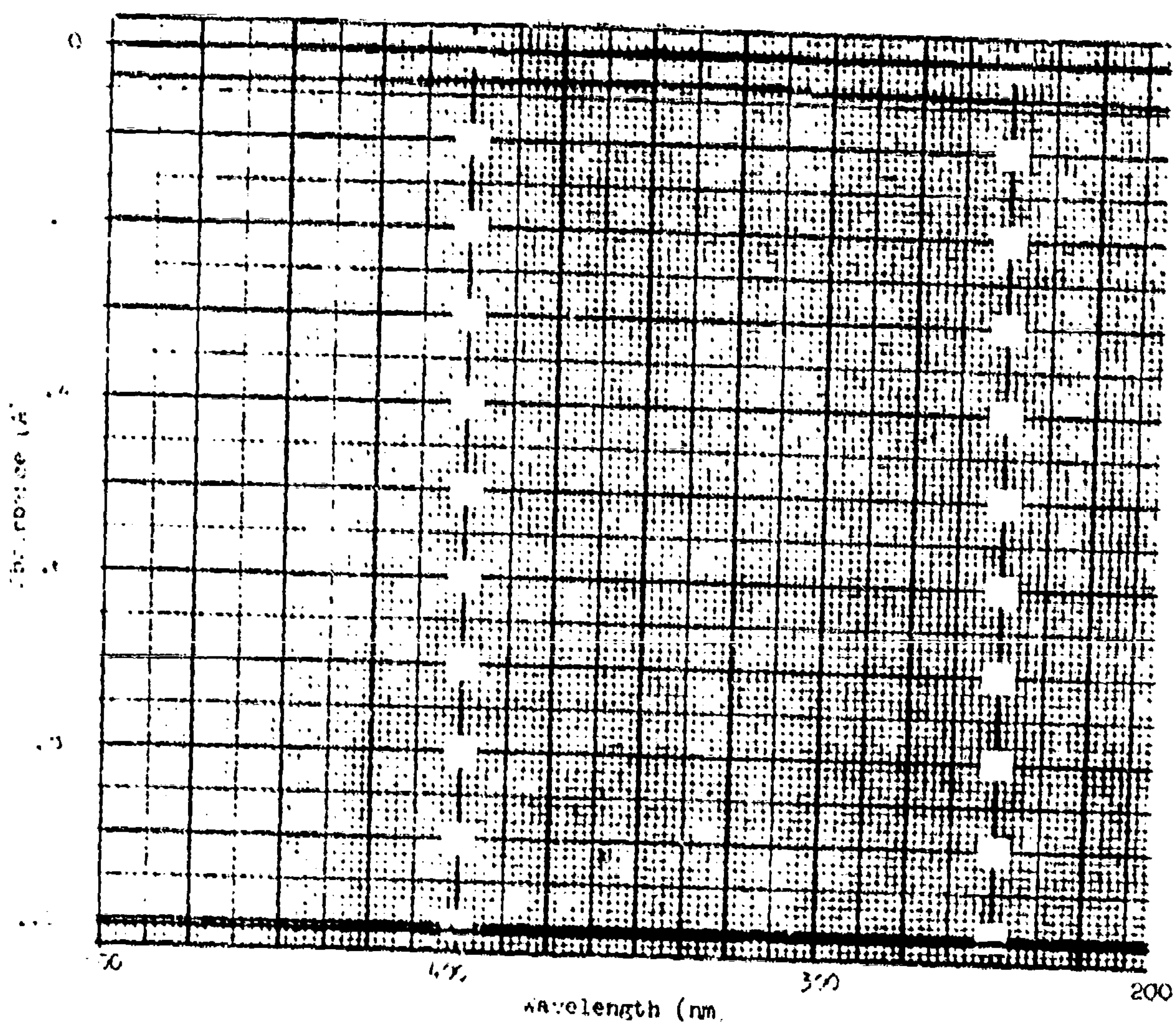


Figure : Transmission of Suprasil 1

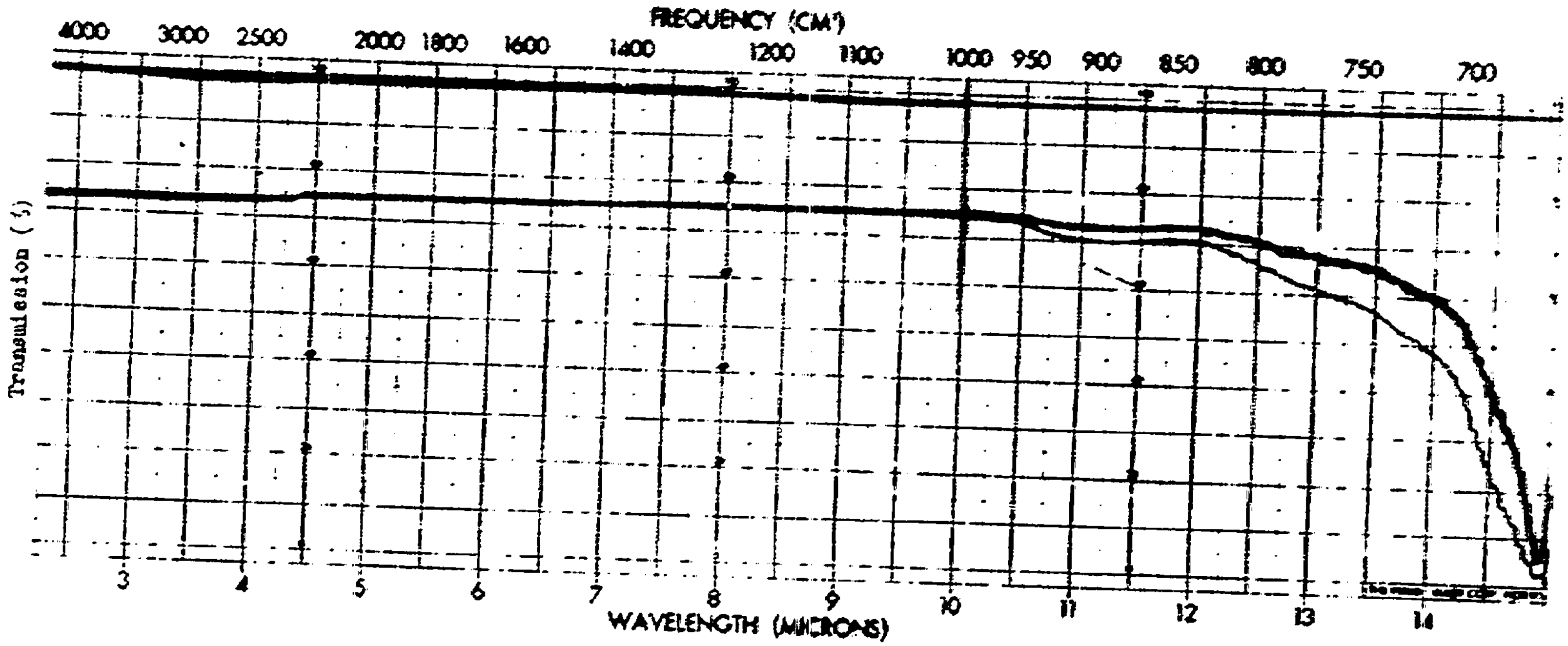
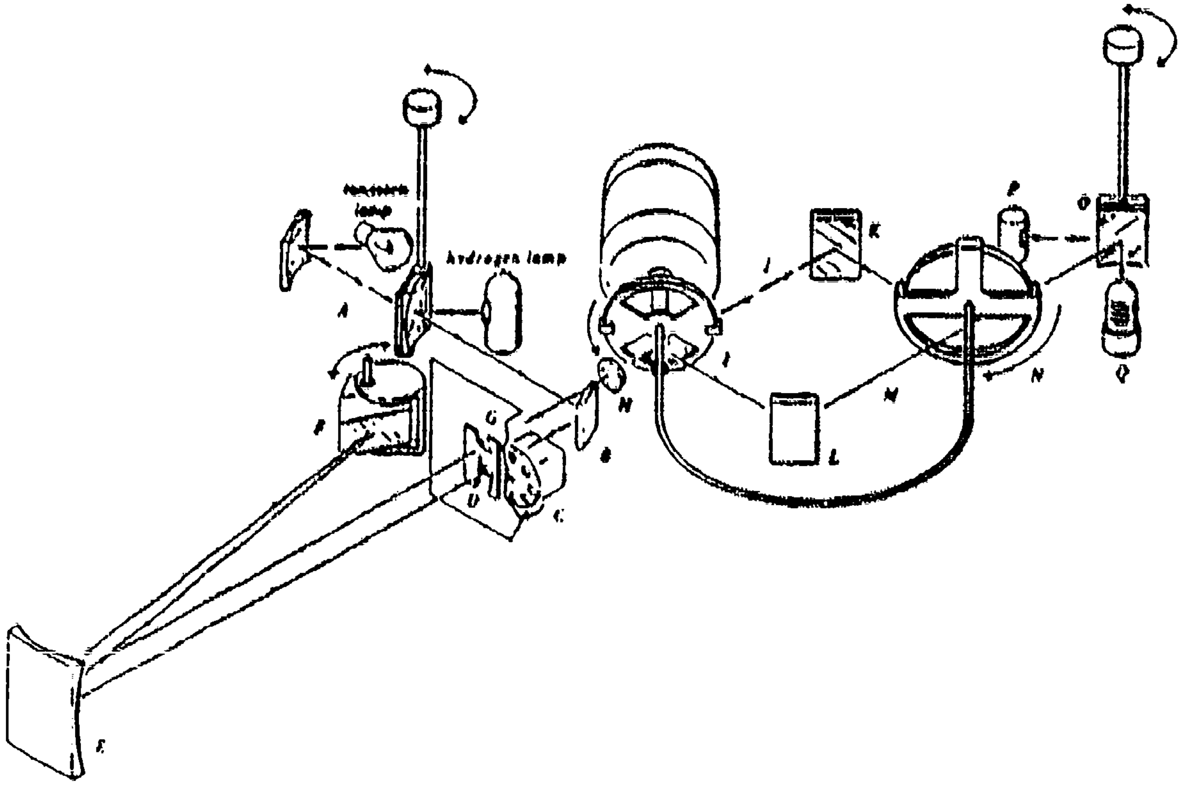
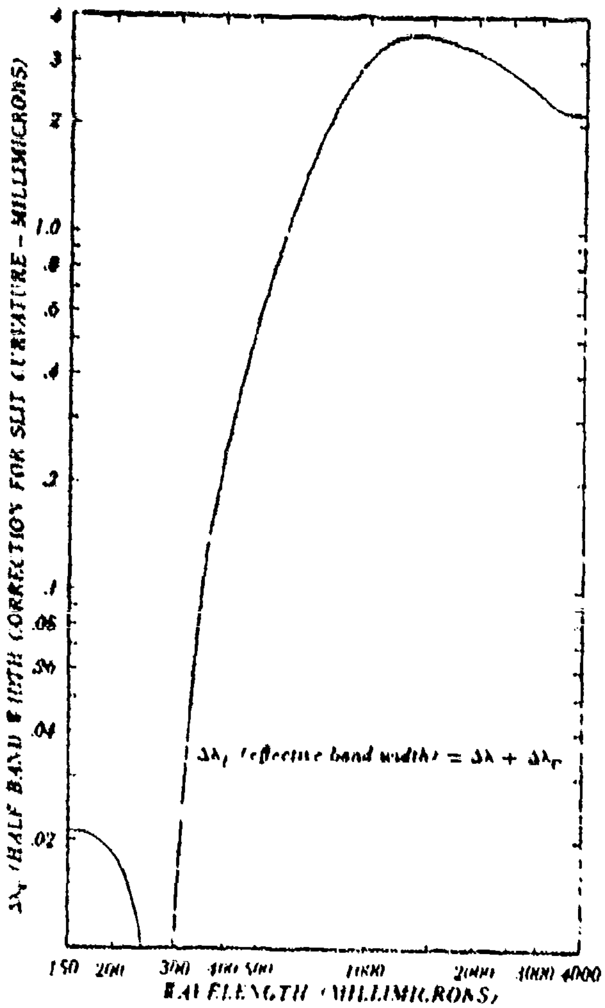


Figure 5: Transmission of Irtran II

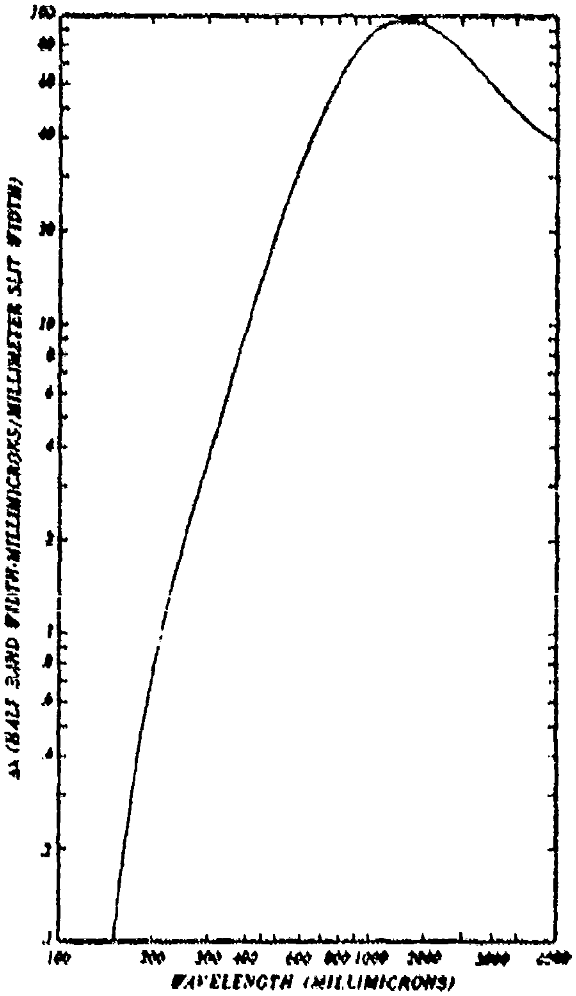


A. source condensing mirror
B. entrance mirror
C. entrance beam chopper
D. entrance slit
E. collimating mirror
F. quartz prism
G. exit slit
H. exit beam condensing lens
I. rotating mirror
J. reference beam
K. reference stationary mirror
L. sample stationary mirror
M. sample beam
N. rotating mirror
O. detector selector mirror
P. lead sulfide cell
Q. photomultiplier tube

Figure [illegible]: Beckman DK-2A Optical Design



Slit Curvature Correction Curve



Instrument Dispersion Curve

Figure : Beckman DK Dispersion Curves

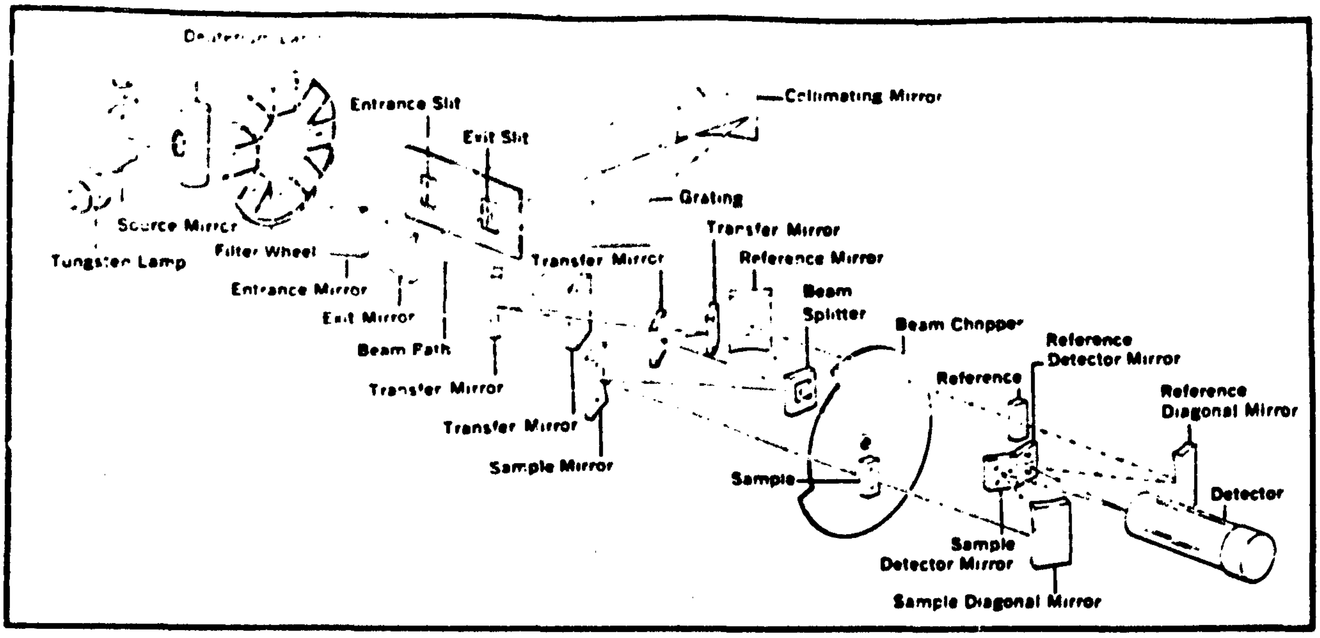


Figure 6: Beckman Acta Optical Layout

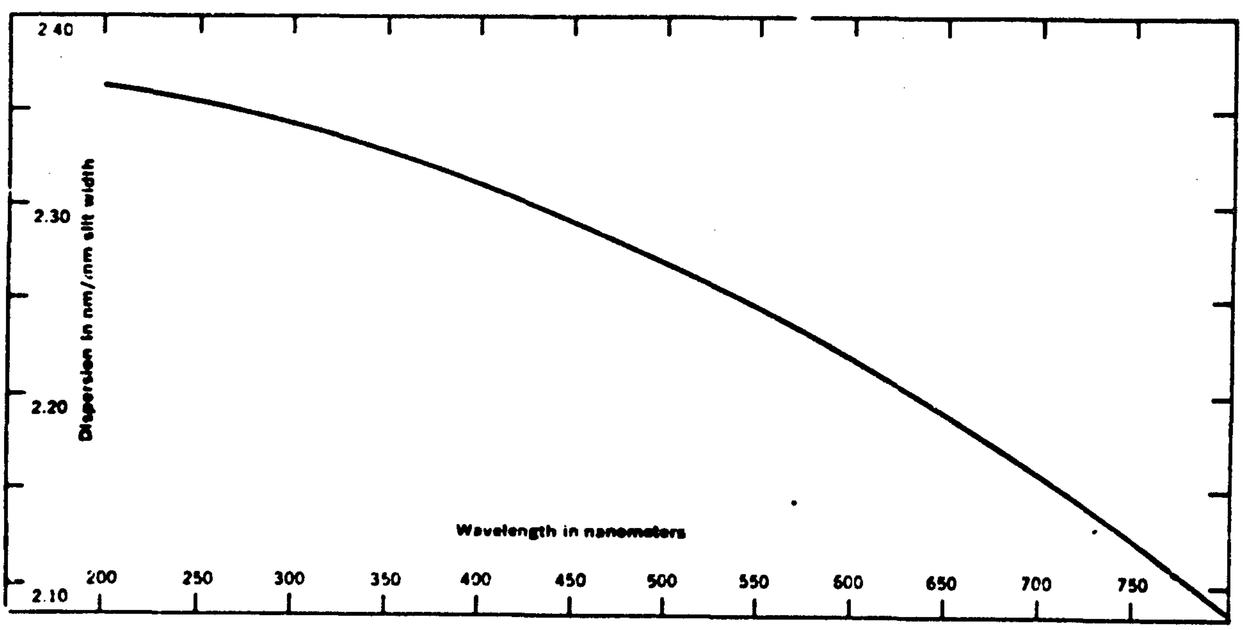


Figure 7: Beckman Acta Dispersion Curve

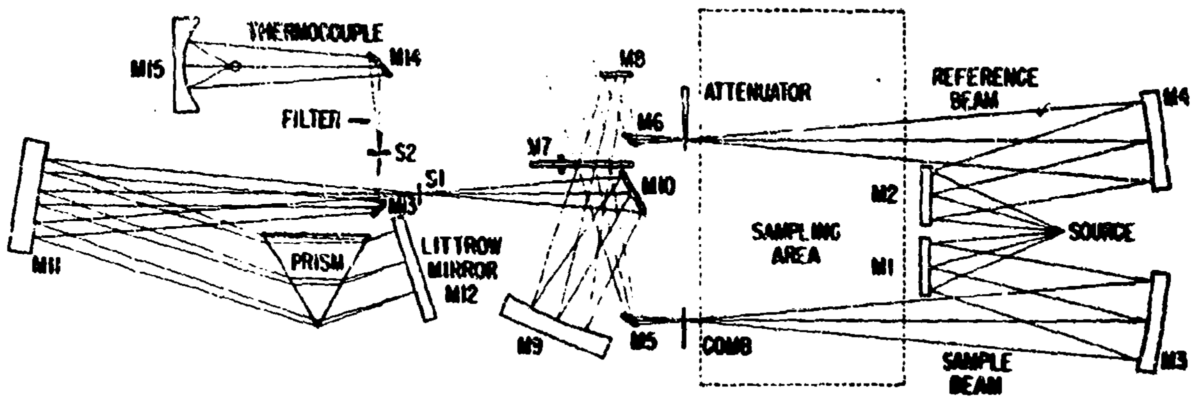


Figure 8: Perkin-Elmer Model 221 Optical Design

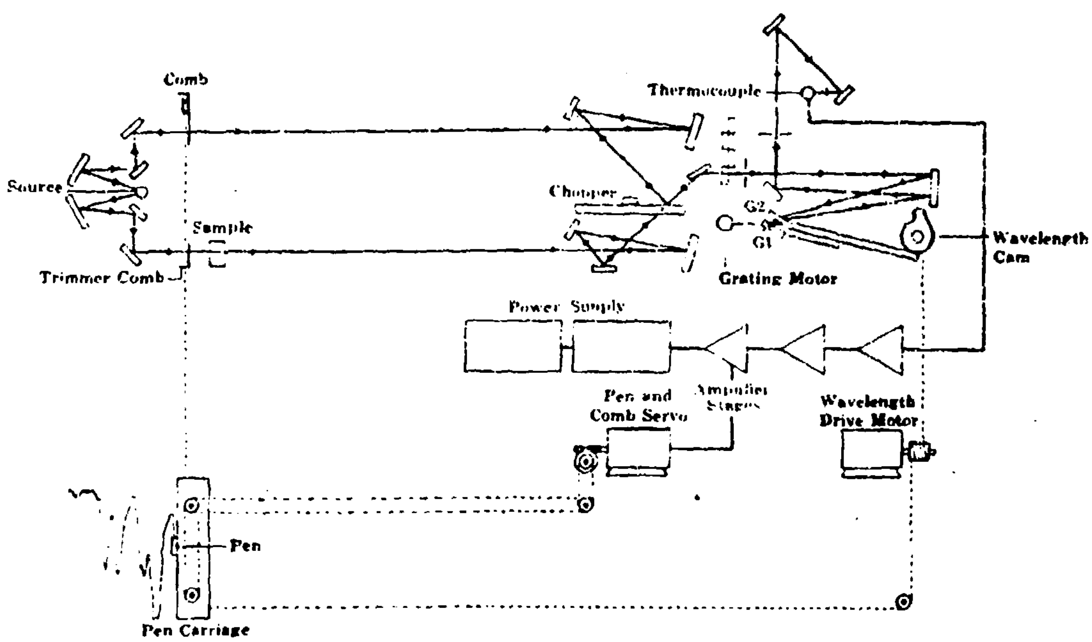


Figure 9: Beckman IR3 Optical Design

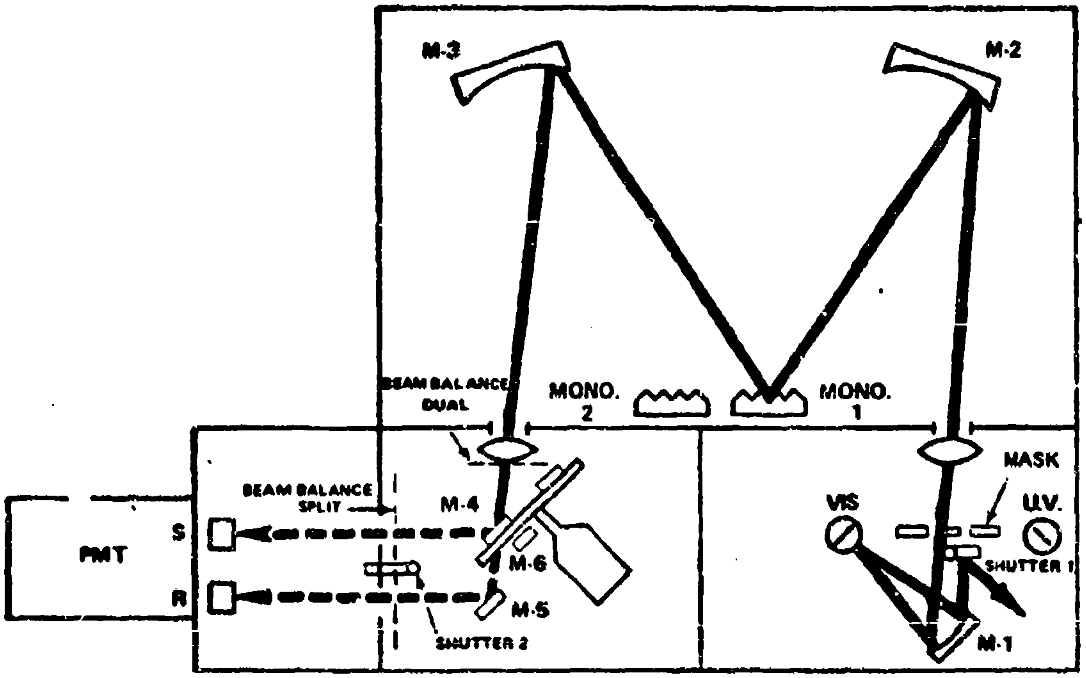


Figure 10: Aminco DW-2 Optical Design

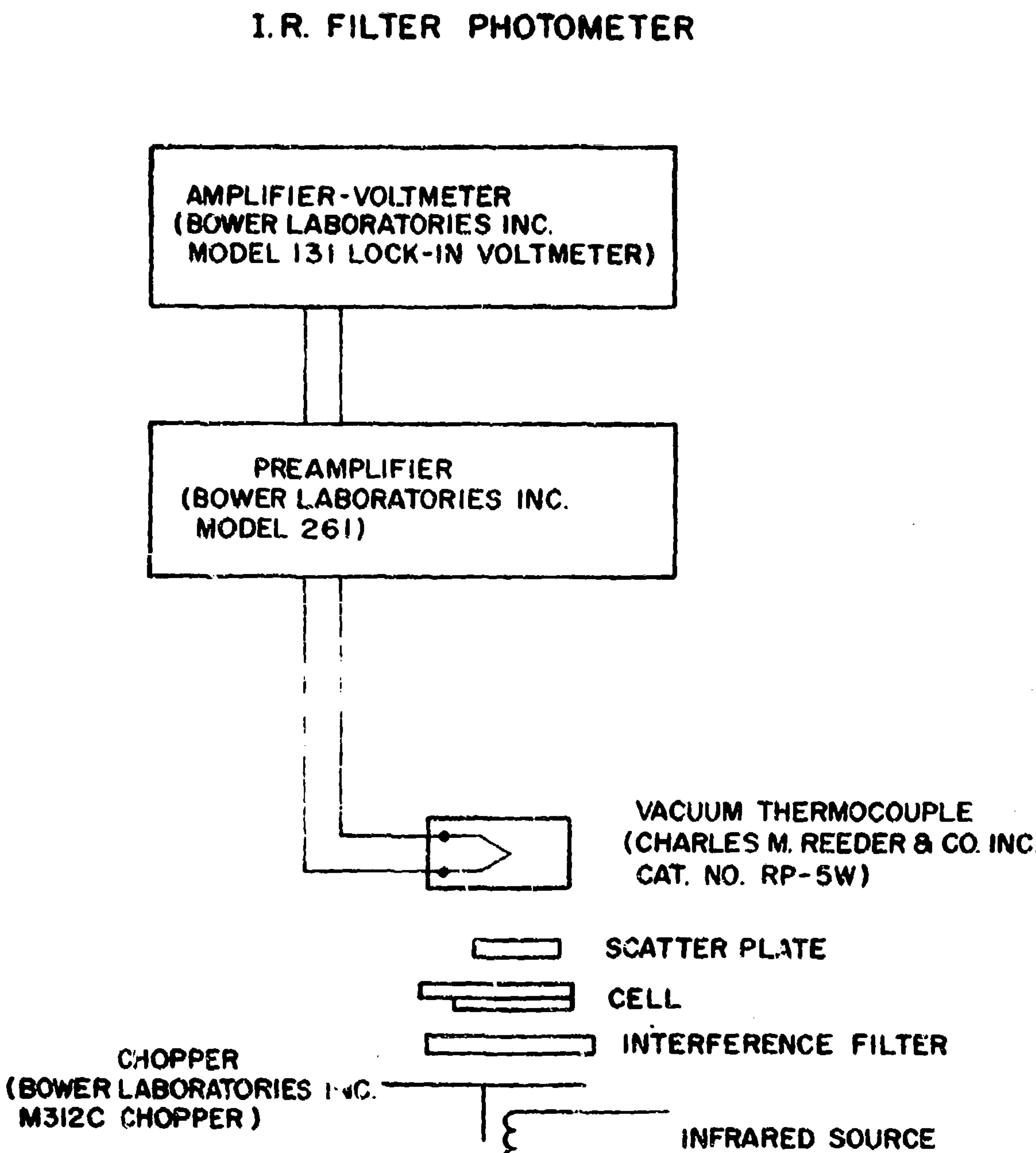


Figure 11: Filter Photometer, Infrared

U.V. FILTER PHOTOMETER

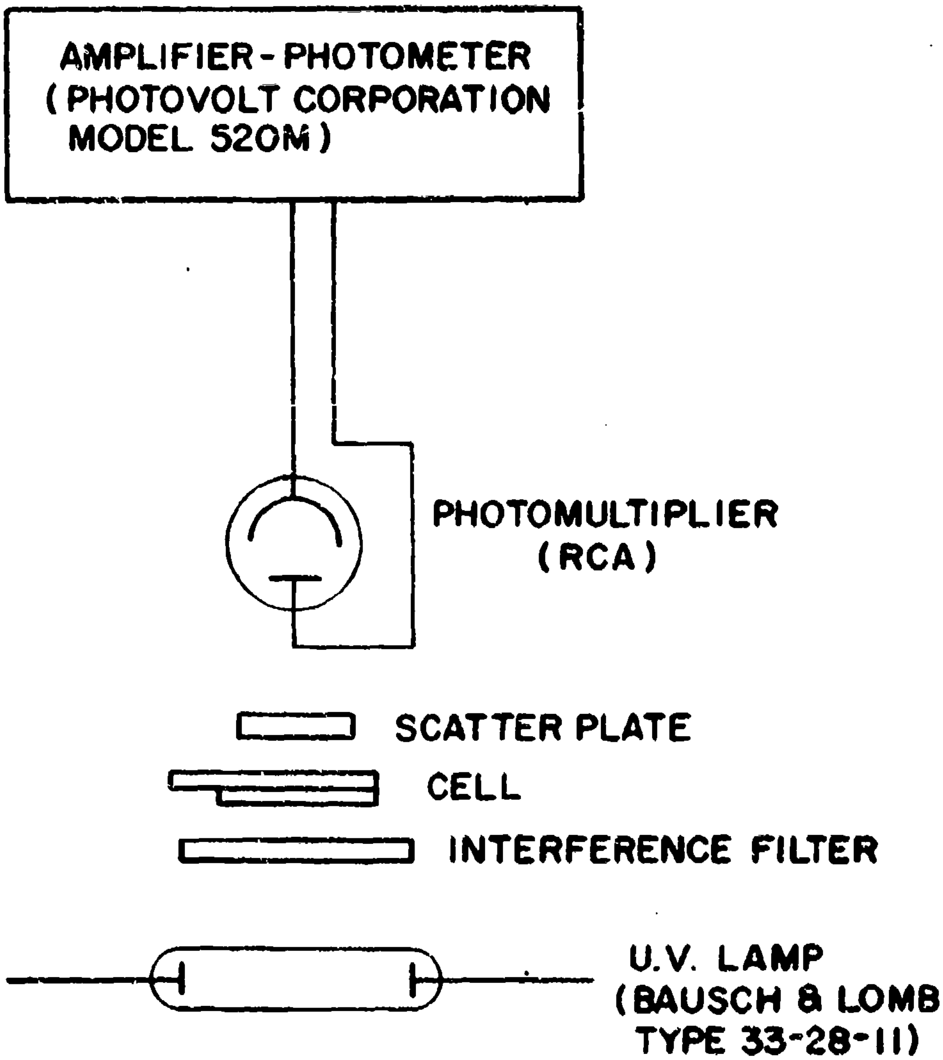


Figure 1[illegible]: Filter Photometer, Ultraviolet

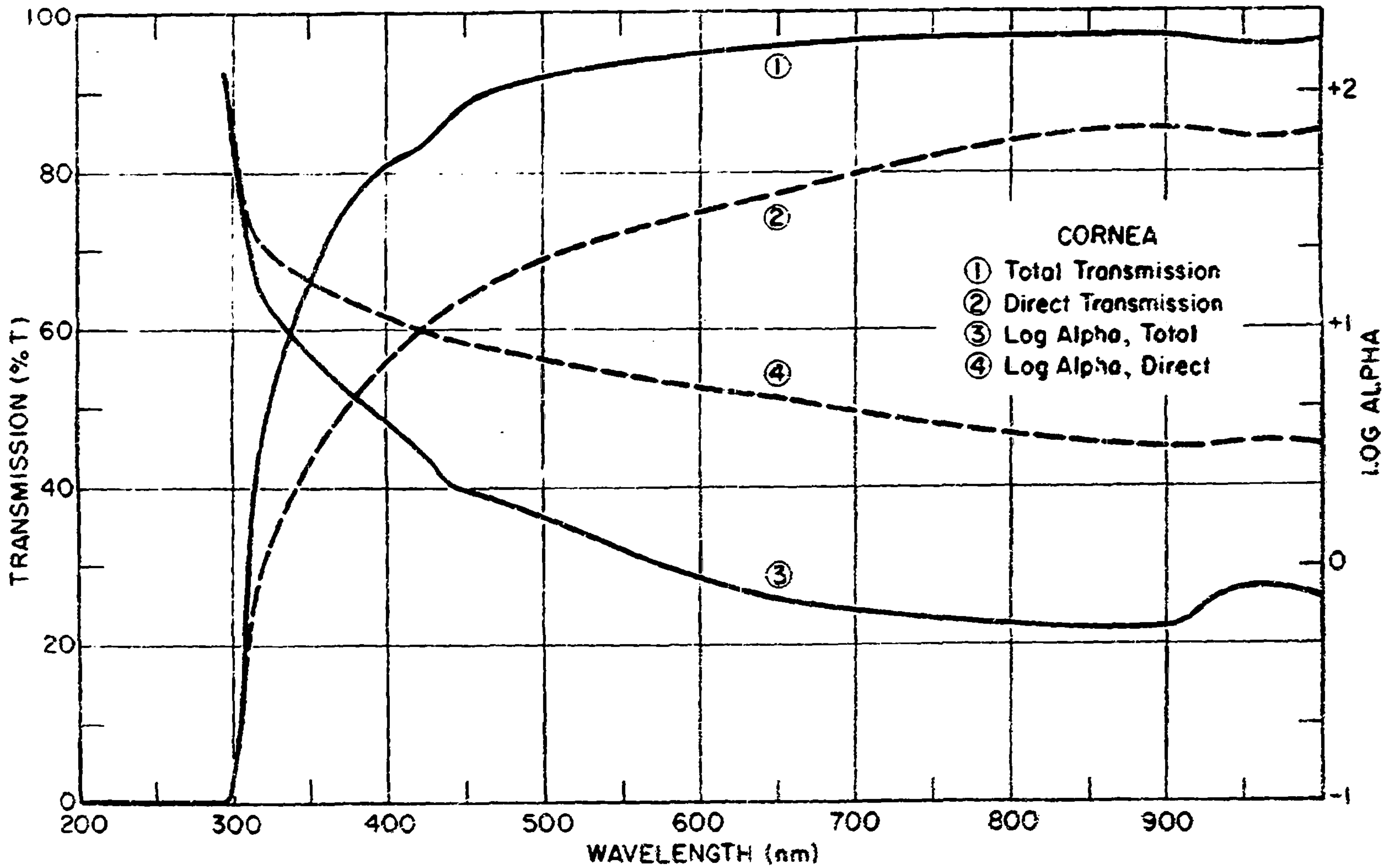


Figure 13: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Cornea of the Rhesus Monkey, 200 to 1000 nm

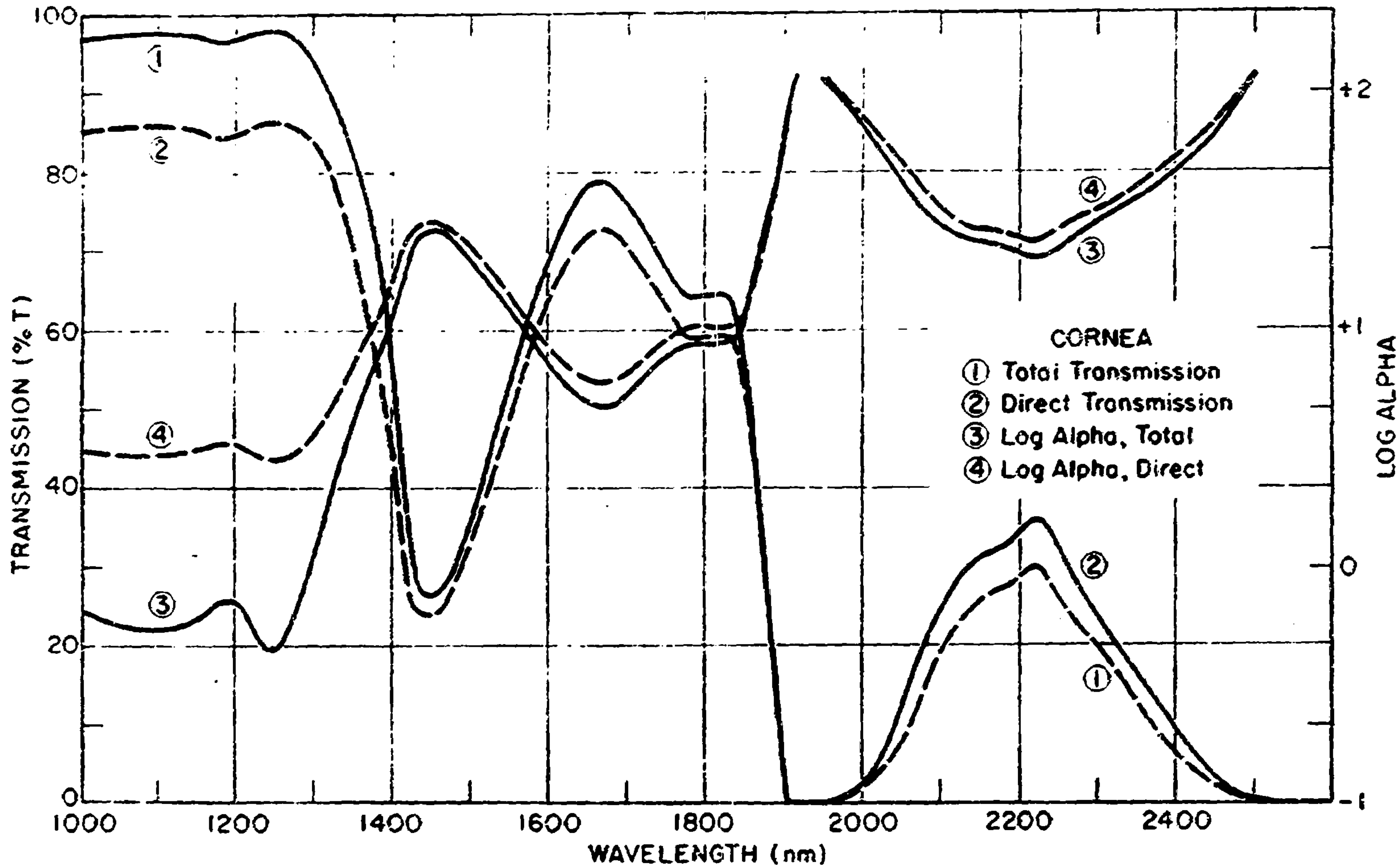


Figure 14: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Cornea of the Rhesus Monkey, 1000 to 2600 nm

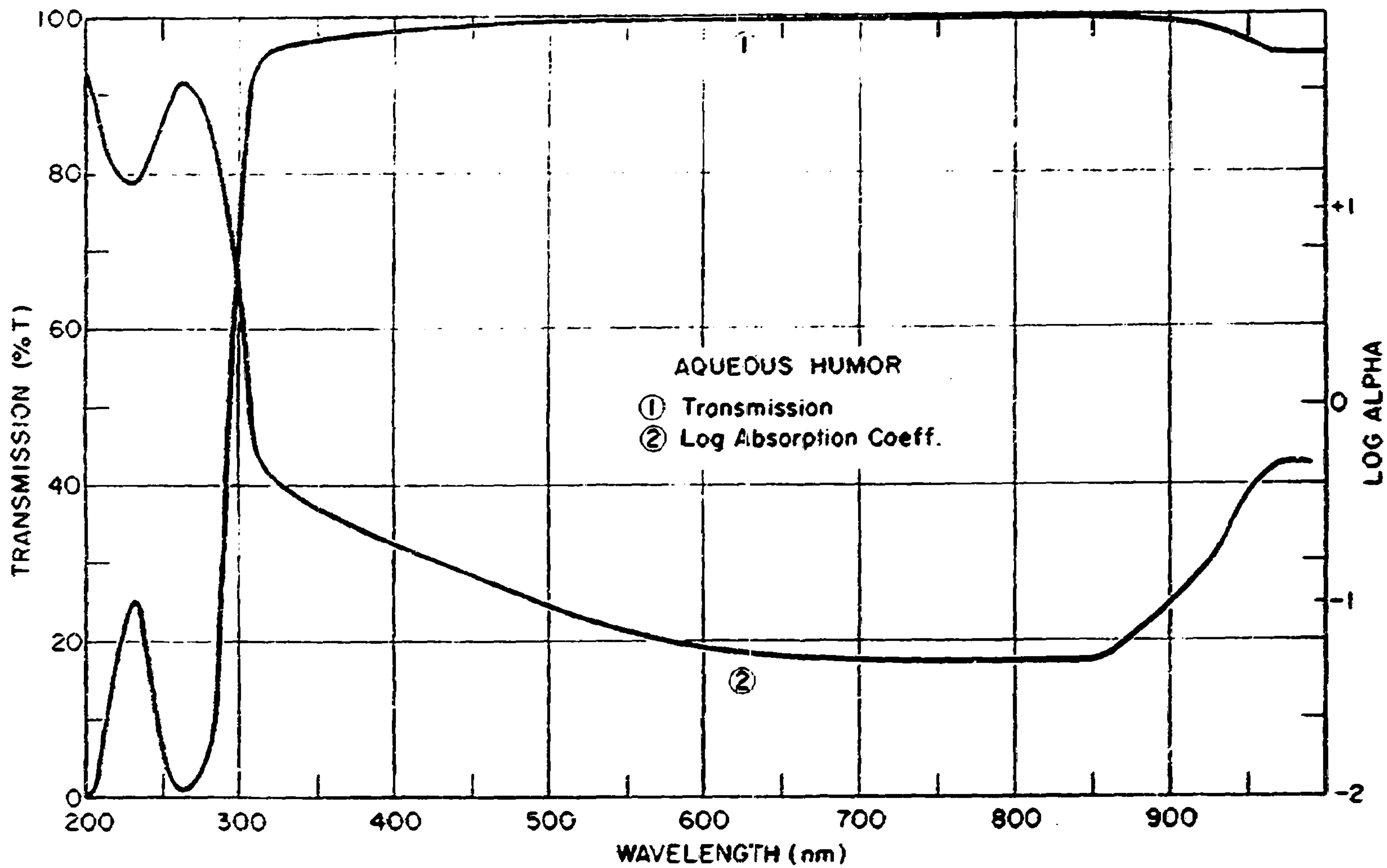


Figure 15: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Aqueous of the Rhesus Monkey, 200 to 1000 nm

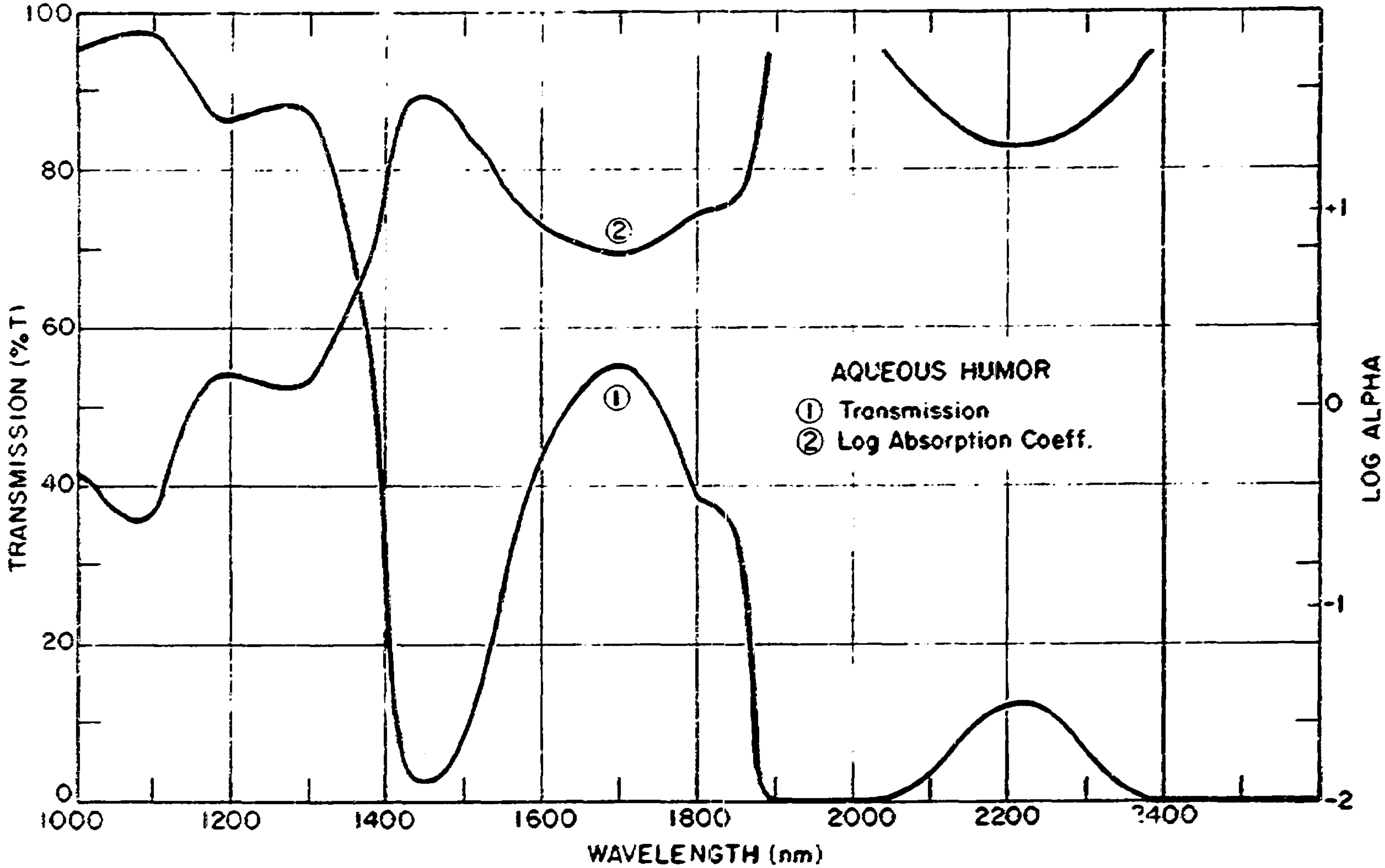


Figure 16: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Aqueous of the Rhesus Monkey, 1000 to 2600 nm

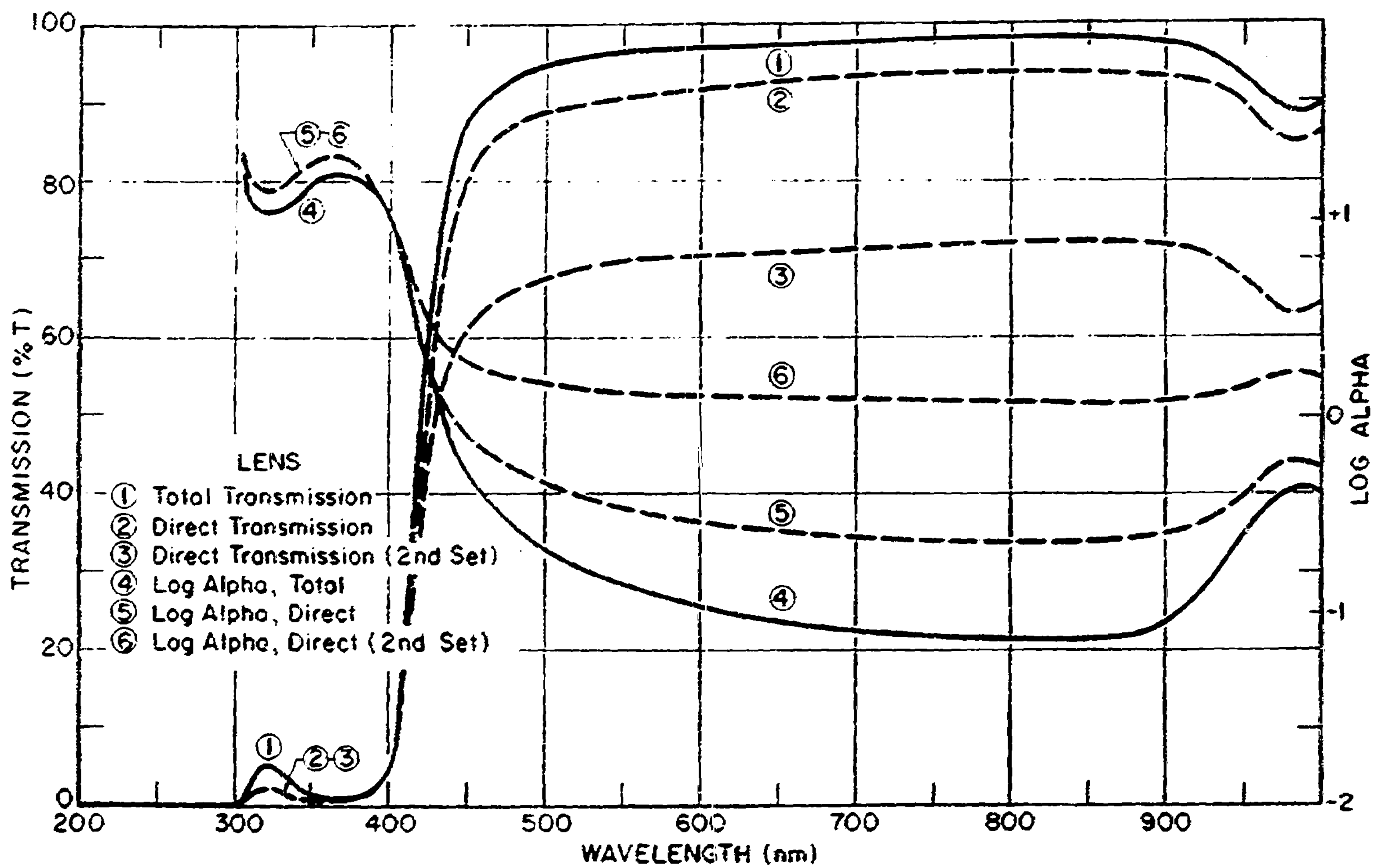


Figure 17: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Lens of the Rhesus Monkey, 200 to 1000 nm

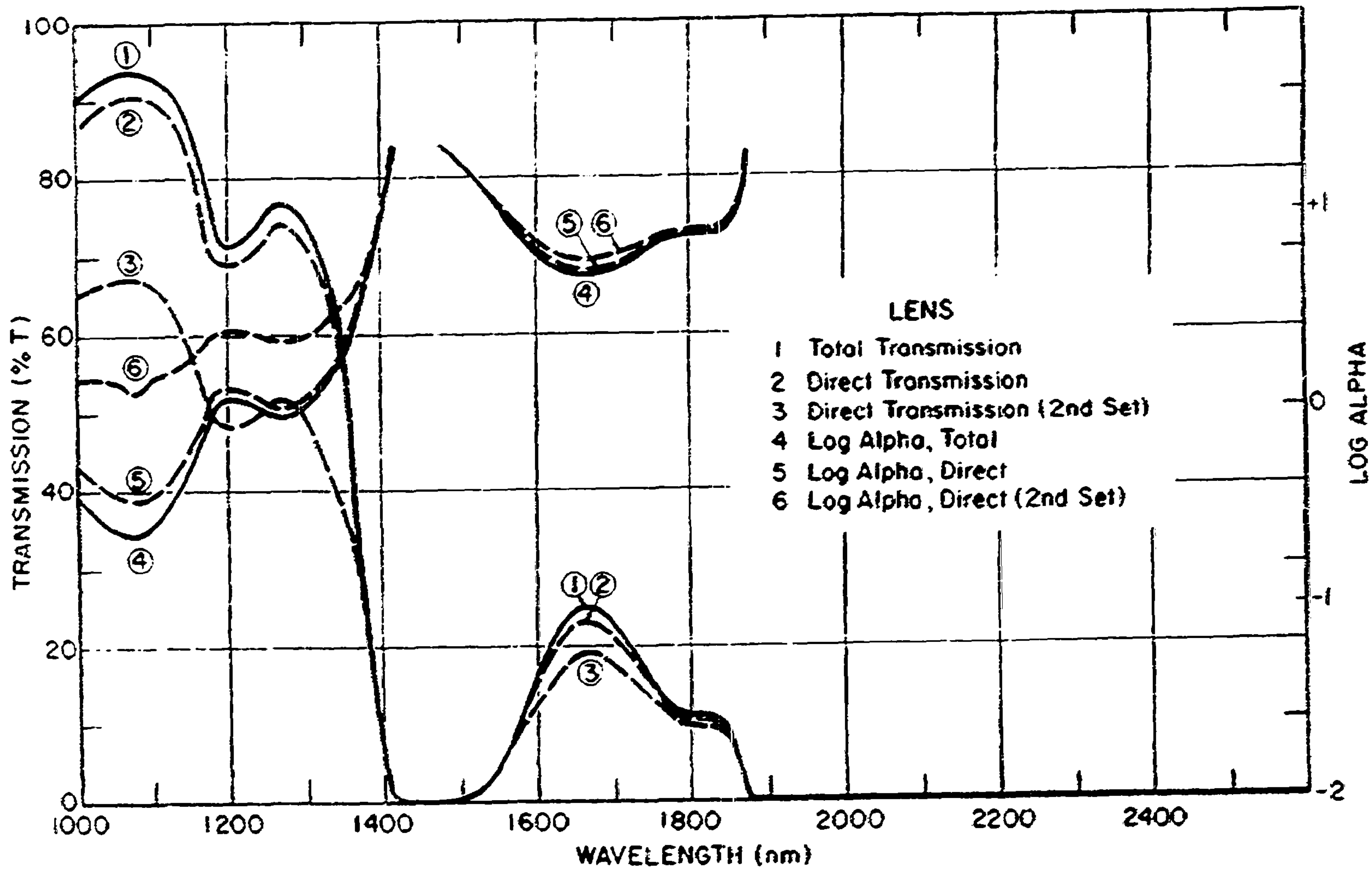


Figure 18: Transmission and Log Absorption Coefficient (per cm^{-1}) of the Lens of the Rhesus Monkey, 1000 to 2600 nm

APPENDIX I: FLUORESCENCE OF THE OCULAR MEDIA

In the section, Discussion of Results, page 16, we related our experience in encountering fluorescence of the cornea when using the filter photometer, and subsequently verifying that it existed not only in the cornea, but also in the aqueous and lens by using a spectrofluormeter. It was found that all three media emitted radiation from 330 to 355 nm when excited with radiation from 260 to 300 nm. In addition, the lens will emit from 445 to 460 nm when excited with radiation from 345 to 375 nm.

A literature search was carried out to determine what was known about fluorescence in the ocular media, and our findings are summarized below.

Cornea: Although we observe fluorescence in the corneas of rhesus monkeys (excitation at 260-270 nm, emission at 330-340 nm) we could find no reports of such fluorescence in human eyes. Utsumi states flatly "The normal human cornea does not fluoresce".

Aqueous Humor: Fluorescence of the aqueous humor has been previously reported. Excitation at 278 nm yields emission at 330 nm. This fluorescence has been attributed to the presence of tryptophan in the aqueous humor.

Lens: Fluorescence of the lens has been reported on many occasions, including:

1. Tryptophan fluorescence - excitation at 278 nm, emission at 330 nm.
2. A yellow, water soluble pigment which fluoresces blue on paper, which occurs in the lenses of many diurnally active species. In man and primates this pigment has an absorption maximum between 365 and 368 nm. This pigment has been identified as L-3-hydroxykynumenine -O-B-D glucose, and is

reported to be relatively constant in amount during aging.

3. L-3-hydroxykynurenine -O-β-D glucose also occurs in the aging human lens as a non-water soluble, non-dialyzable, protein-bound pigment. It accumulates with age, and has been associated with exposure to ultraviolet light. The pigment may be formed by photooxidation of tryptophan present in normal protein of lens. Absorption maximum at 366 nm, excitation at 360 nm yields 444 nm emission.

Other kynurenine derivatives may also be present. This appears to account for the pattern normally seen in the human lens of being nearly colorless at birth, very pale yellow as a child, and increasingly yellow or amber with aging. Water insoluble (albuminoid) protein also increases with aging, as does scattering of light in the lens.

Literature Reviewed:

Cooper and Robson, J. Physiol. (1969) 203, 411-417

Absorption spectra of lenses (both whole lenses and solutions) of humans, baboons, rhesus monkeys, squirrel monkeys, and bush babys all had yellow, water-soluble pigment with absorption maximum between 365 and 368 nm. Evidence for build up in adult human lens of a non-water soluble pigment with maximum absorption of about 330 nm, in addition to the water-soluble pigment. Thus absorption in blue end of spectrum is increased, in aging, and λ maximum shifts from 366 nm for young human beings to 331-335 nm in those aged 52-87 years.

Grover and Zigman, Exp. Eye Res. (1972) 13, 70-76 "Coloration of Human Lenses by Near Ultraviolet Photo-oxidized tryptophan"

Used both whole human lenses and solutions of lens proteins. Showed that in presence of tryptophan, exposure to ultraviolet light yielded pigment irreversibly bound to protein. Ultraviolet and tryptophan treatment gave increase in absorption at 444 nm, similar to increase at 440 nm that is observed in aging human lens. Showed normal human gamma-crystallin fluoresces at 340 nm when excited at 280 nm, after ultraviolet tryptophan treatment saw fluorescence at 440 nm due to 360 nm excitation.

Harding, Exp. Eye Res. (1972) 13, 33-40

Previous experimenters had reported a urea-insoluble protein in lens - Harding shows evidence that this is an artifact which can be avoided by working anerobically. With aging, accumulate urea-soluble, water insoluble (albuminoid) protein, in both man and rat.

Kurzel et al, Exp. Eye Res. 17 (1973) 65-71

Graphs of lens fluroescence in both ultraviolet and visible. Excitation at 330 nm yields fluorescence at 350 nm, attributable to tryptophan, in normal lens. Excitation spectrum is very complex. Definite maxima at 300 and 400 nm, minor maximum at 425, 470 and perhaps 330 nm. Kynurenine has emission maximum at 465 nm when excited by 300, 350 or 400 nm light. 3-hydroxhkynurenine has absorption maximum at 425 nm, secondary maximum at 375 nm.

Lerman, Ch. 50 of Contemporary Ophthalmology Honoring Sir Stewart Duke-Elder, Williams & Wilkins, (1972) "Lens protein in Aging and Cataract Formation"

Ocular lens is almost entirely water and protein, with >95% of proteins being water soluble, at birth. Percentage of insoluble (albuminoid) protein increases may be >50% in lens of senile individual. Water soluble protein-gamma crystallin contains fluorescent compound with λ maximum (absorption near 280 nm). Pigment is protein-bound, and emits at 444 nm when stimulated by 278 nm, 305 nm and 370 nm light. Fluorogen accumulates with age.

Lerman Israel J. Med. Sci. 8, 1582-1589

Lens scattering increases with aging, perhaps due to increase of large albuminoid proteins plus changes in spatial arrangement. Lens fluoresces at 444 nm, when stimulated by 278, 305 and 370 nm light.

Pirie, Ch. 51 of Contemporary Ophthalmology (previously cited) "The Effects of Sunlight on the Proteins of the Lens"

Exposed solutions of lens proteins to sunlight. All became pale yellow in a few hours, deep yellow in a few days, as did solutions of serum albumin, tryptophan, and tyrosine. Reported that sunlight

caused a fall in absorption at 276 nm, and a rise in absorption above 300 nm and below 265 nm. Evidence of destruction of tryptophan by ultraviolet.

Satoh, Acta Soc. Ophthalmol. Jap. 75, 1627
Isolated four major fractions with molecular weight less than 1000 from human lens protein. All absorb at 260 nm, with a shoulder at 300 - 350 nm. All fluoresce (410 nm-480 nm) when stimulated by 330 nm - 380 nm.

Satoh, Acta Soc. Ophalmol. Jap. (1971) 75, 1627-1629 (English Abstract)
Gel filtration yields four fluorescent fractions from the soluble portion of aged human lenses. All possess absorption maximum at about 260 nm with a shoulder between 300 nm and 350 nm, and each fraction fluoresces between 410 and 480 nm when excited by near ultraviolet (330 nm to 380 nm).

Utsumi, Acta Soc. Opthalmol. Jap. (1971) 75, 1363=1373 and 76, (1972) 55-64 (English Abstract)
The normal cornea does not fluoresce (note cornea contains no tryptophan in its structural protein). However, corneal scar tissues inflammatory opacity, arcus seniles and various other conditions do yield fluorescence.

Van Heyningen, Nature (1971) 230, 393 "Fluorescent Glucoside in Human Lens"
Observed yellow peptide in protein-free dialysate of human lenses removed for cataracts, pigment fluoresced blue-white, on paper. Identified as glucoside of L-3 hydroxykynurenine.

Van Heyningen, Pro. of Biochem. Soc., Biochem. J. 123, 30-31, July 1971
Major fluorescent component of lens is the same in man and baboon (which have very similar absorptions, according to Cooper and Robson) identified as O-B-D glucoside of 3-hydroxykynurenine.

Van Heyningen, Exp. Eye Res. (1972) 13, 155-160 "Some Observations on Postmortem Lens"
Confirms that under age 50, human lens is generally transparent; above that, visible opacities. "Lens of newborn baby is almost colorless

and that of a child very pale yellow. Older lenses are shades of somewhat darker yellow". Normally, nucleus is not darker than water - if this is observed, appears to be pathological.

Zigman, Science (1971) 171, 807-809 "Eye Lens Color-Formation and Function"

Reported photooxidation of normal amino acids in lenses by ultraviolet light would increase absorption at 365 nm and lead to fluorescence-stimulation at 360 nm yielding fluorescence at 440 nm. Normally only tryptophan is fluorescent, with stimulation at 280 nm yielding fluorescence at 330 nm.

Zigman et al, Exp. Eye Res. (1973) 15, 201-208

Exposure to ultraviolet light interferes with lens protein synthesis and catalyzes the formation of insoluble protein.

Zigman et al, Esrael J. Med. Sci. 8, 1590-1595

Both aqueous and lens fluoresce. Stimulate aqueous at 278 nm $\Rightarrow$ 330 nm fluorescence.

APPENDIX II: ABSORPTION OF WATER AND SALINE

As an additional task on this program, we agreed to make measurements on the transmission of water and saline solution. In indicating a desire to do this, we exhibited a degree of naivete in under-estimating the magnitude of the problem but it soon became apparent once we began the actual measurements. As a result, what we are reporting here is a discussion on three topics, i.e., a brief description and a bibliography of the previous work in this area, a comparison of limited data from our measurements, and a suggestion on new approaches that may overcome some of the previous measuring problems.

Methods: In the spectral region from 200 nm in the ultraviolet to 15 μm in the infrared the transmission by pure water in the liquid phase varies from "completely" transmitting to "completely" absorbing. Defining it in more scientific terms, one finds that the Lambert absorption coefficient varies from less than 10^{-3} to greater than 10^{4}. It is this great range of more than seven orders of magnitude that makes the experimental measurements a challenging task, with the problem compounded by the fact that there is no direct way for measuring absorption. As a result, two indirect methods are used, i.e., the measurement of either the spectral transmission or the spectral reflectance.

A bibliography of work in this area is attached, along with brief abstracts to indicate the methodology used. Values from nine of these references are incorporated in Table VII.

Spectral Transmission: The fractional transmittance at a specific wavelength of water in an absorption cell of thickness b is given by the relation:

$$I/I_o = (1-R)\ (1-A)e^{-\alpha b}$$

where R is the fraction of the energy reflected at the cell windows, A is the part absorbed by the cell windows, and α is the Lambert absorption coefficient. There are experimental difficulties in using this relation to de-

termine α. In regions of high transmission, one must precisely correct for R and A. The effect of reflection R at the outer faces of the cell windows can be eliminated by putting a window of the same material (or of the same index of refraction) in the reference beam of the spectrometer to adjust I_o for this reflection loss. However, to adjust for reflection losses at the inner surfaces of the cell, between the cell windows and the water, two windows are used in the reference cell, separated by a very thin layer of water. If one uses windows of equal thickness in both beams, then one has corrected for both R and A in the above equations. The absorption by the thin water layer in the reference beam can either be neglected if very thin with respect to the sample cell thickness, or can be corrected for. In our measurements, this layer was 0.1 mm thick, compared with a 10 mm and 75 mm thickness in the sample beam, and our results were corrected for this. However, even with corrections for window reflection and absorption, one ultimately reaches a point below which the error in this measurements are equal or greater than the small amount of energy that is absorbed. This error can come from several sources, including water purity, window cleanliness, refraction effects (discussed later) and instrumental noise. In our measurements, we estimate that uncertainties in α can be as great as 8% at α = .05 cm^{-1}, increasing to 30% at α = .005 cm^{-1}.

In regions of low transmissions, one encounters other problems, with the primary one being the accurate control of the thickness b. At high absorption, it is necessary to work with a water thickness of a few micrometers in order to obtain a measureable transmission, but in doing this, the thickness becomes difficult to control. We made no measurements below 25 micrometer in thicknesses, but even here, found it necessary to measure the thickness without distrubing or dismantling the cell. This was done by using the technique of recording and utilizing the spacing of interference fringes to calculate the thickness. However, it is uncertainties of the thickness of the absorbing film that limit the precision with which α can be determined in regions of strong absorption. Also, at the longer wavelengths (greater than 5 μm), stray radiation from shorter

wavelengths can produce errors in regions of high absorption. Further, the lower signal-to-noise ratios that one encounters through all regions of the infrared using a thermocouple detector severely limits ones ability to utilize scale expansion techniques to the extent that they are used in ultraviolet/visible spectrophotometers. From our experience in working in the infrared region, we estimate our uncertainty in α of 5% at $\alpha = 100\ cm^{-1}$, increasing to 15% at $\alpha = 1000\ cm^{-1}$.

Spectral Reflection: To overcome the problem of inaccuracies associated with measuring the transmission at wavelengths that are highly absorbed, several investigators have gone to the technique of measuring the reflection from the surface of water and used the Cauchy reflection equations for determining α. For example, at reflection normal to the surface:

$$R = \frac{(n-1)^2 + (\alpha\lambda/4\pi)^2}{(n+1)^2 + (\alpha\lambda/4\pi)^2}$$

Here, R is a function of not only the absorption coefficient but also the real component of the index of refraction. As a result, when one tries to use this relation to determine α by measuring R, he must use an accepted value of the index, and the errors associated with it. This works reasonably well at high values of α, but the accuracy becomes poor at low values, where errors in n become an overriding factor. An example of this is the work of Pontier and Dechambenoy (10) who, in using this technique obtained α values systematically higher. As a result, those reviews that have tried to compile the best values from the published works of various investigators have generally accepted the transmission measurements for low values of α and the reflectance measurements for high values.

Our Measurements: To determine the absorption coefficient of water, we used the transmission method. In the ultraviolet and visible regions we have been using cell path lengths of both 10 mm and 75 mm, with an identical cell of 0.1 mm in the reference beam. The longer cell appeared desirable in order to have greater changes in transmission at those wavelengths where water is highly transmitting. However, we found that large

shifts were encountered such that transmissions of greater than 100% were measured at some wavelengths. This discrepancy was traced to the long path length cell, which acts as a thick lens when placed in a converging or diverging bundle of radiation, thereby changing the size of the bundle at the photodetector. This problem was extensive on both the Beckman DK-2A and the B & L 505, and considerably less (but still a factor) on the Beckman Acta. An attempt to compensate for this by introducing an index of refraction correction was unsuccessful, so all of the data presented here was obtained using a 10 mm cell and scale expansion. The refractive errors are still present using this shorter path-length, but are now decreased to the order of magnitude of other measuring errors.

In the infrared region, all measurements were necessarily made at short path-lengths (25 to 50 micrometers), with the result that we can not get meaningful data when the absorption coefficient approaches 10^3. In order to work in these more abosrbing regions, we must find better ways of forming accurately measurable water paths of less than 20 microns.

To compare the published data and our measurements, we have selected several wavelengths where it was felt that our methodology produced reasonable results. These are compiled and compared in Table VII with the published values from the first nine references given in the bibliography. Our values are an average of eight individual runs. The overall spread of these values are indicated in parenthesis under the average value in the table. One must keep in mind that a small difference in the transmission reading results in a large difference in the absorption coefficient. For example, a difference of 0.5% in the transmission at 2.2 μm results in a 11% difference in α. Likewise, at 3.8 μm, a transmission difference of 0.5% changes α by 2.2%. In comparing our values with the others, it appears that a better agreement would result if our transmission measurements were from 1/2% to 1% higher than actually observed.

Summarizing then, there are two problem areas that have plagued investigators in the determination of the absorbing ability of liquid water. These are 1) the accurate measurement of absorption in regions of high

transmission, and 2) the accurate measurement of reflection in regions of high absorption.

In the regions of high tranmisssion (primarily in the ultraviolet and visible), one must go to very long path lengths in order to have a measureable change of transmission, and in doing this, one immediately encounters two problems. The first is an optical problem, arising from the refraction effects of the long water path. Almost all spectrophotometers have their radiation beams converging and/or diverging in the region where the samples are placed, in order to have a maximum amount of energy on the photo detector and still use a minimum sample size. As a result, if one uses a very long sample whose index of refraction is different from that of air, the size of the radiation bundle at the detector will be changed, and as a result a change in detector output. For example; on our Beckman DK-2A Spectrophotometer, an increase in the signal output resulted when a 75 mm cell of water was used in the sample beam, with an indicated transmittance of "108%" at 500 mm. The Beckman Acta showed a similar effect, but to a smaller extent. The most straight forward answer to this problem is to collimate the beam passing through the sample. This has been done in some specially constructed spectrophotometers in the past, but we know of none on the market at the present time. The effects can be partially over-come by the use of apertures and diffusing plates, but with other limitations introduced. One obvious way around the problem would be to use a tunable laser as a source on a spectrophotometer, thereby making use of the collimation of a laser beam.

Another and equally serious problem in making measurements in the high transmission region of water is the need for extremely high purity of the water when using long path lengths and the difficulties associated with determining when one has "pure" water. This latter problem is compounded because impurities can cause either a decrease or increase in apparent transmission. The latter case comes about if an impurity can be induced to fluoresce when excited with the wavelength being measured. Figure 19 shows the variations in the ultraviolet absorption of several "pure" waters collected around our laboratories, including those that were double-distil-

led. Water that was used was distilled in all-glass system after overnight refluxing with $KMnO_4$. This procedure removes organic materials which can co-distill with water in a normal distillation. Even double-distilled and de-ionized water suitable for atomic absorption work may contain enough organics to interfere with absorption measurements. Also included in Figure 19 is the absorption curve of a "Hospital Grade" saline solution. Although this sample has transmission very close to that of pure water in this region of the spectrum, we would expect the variation between samples to vary considerably, depending on the original purity of the water and sodium chloride, and the handling of the product in bottling. All of the samples listed in Figure 19 showed no differences in their absorption in the infrared region because the absorption by the water is many orders of magnitude greater than that by any impurities in the water or saline.

The principle problem in obtaining an accurate measurement of transmission in highly absorbing spectral regions (primarily the infrared) is that of obtaining a measureable amount of energy at the detector of the spectrophotometer. Two apparent ways of overcoming this would require modifying conventional instruments. One could use one of the many detectors which are considerably more sensitive than a thermocouple, and accept the wavelength restrictions associated with them by continually changing detectors in moving from one spectral region to another. The other would be to replace the conventional radiation source with a laser that is tunable in the infrared, thereby obtaining considerably more radiation per spectral-bandwidth (see comment on page 21).

1) Bayly, Kartha, and Stevens, Infrared Phys., Vol. 3 1963, 211 Wavelength Range: 700 nm - 2.5 μm
   Method: Direct absorption measurements. Graphs of data impossible to read accurately. No correction for effect of refraction of radiation beam by water.

2) M. Centeno, J.O.S.A., Vol. 31, March 1941, 244 Wavelength Range: 1.0 μm - 18.0 μm

Method: Review of existing data of reflection and absorption; analysis using Cauchy equation.

3) Curcio and Petty, J.O.S.A., Vol. 41, no. 5, May 1951, 302 Wavelength Range: .7 μm - 2.5 μm

Method: Direct absorption measurements. Used collimated beam, so that pathlength could be varied without creating error due to refraction of beam by water. Excellent study -- but covers only near infrared.

4) Felix Franks, ed., Water: A Comprehensive Treatise, Vol. 1, 202 Wavelength Range: 275 μm - 3.4 μm

Method: Direct absorption measurements and literature review. Good values of α in OH-stretching region.

5) Hale and Querry, Applied Optics, Vol. 12, no. 3, Mar. 1973, 555 Wavelength Range: 200 nm - 200 μm

Method: Literature Review, and subtractive Kramers-Kronig analysis of published absorption data to generate values of refractive index.

Absorption data was obtained from 58 articles and books; data was plotted to yield best visual fit, weighting the curve "in favor of data reported by authors who in our judgement used careful experimental procedures".

This review had the benefit of several recent studies (including our references 10, 11, 12, 13, 14, and 15 not available at time of reference 6).

6) Irvine and Pollack, Icarus, Vol. 8, 1968, 324-360 Wavelength Range: 200 nm - 200 μm

Method: Literature review: Used published absorption values and Cauchy equation to generate values of refractive index.

Absorption data from 200 nm - 650 nm is based entirely on work of Dorsey, "Properties of Ordinary Water Substance", published in 1940; this work utilizes some very old data.

As noted above, this review lacked the benefit of a number of recent infrared studies, and neglected several ultraviolet studies.

7) L.D. Kislovshii, Optics and Spectroscopy, Vol. 7, no. 3, Sept. 1959, 201 Wavelength Range: 2.2 μm - 100 μm

Method: Calculated values of absorption peaks.

8) Lenoble et Saint-Guilly, Comptes Rendus, Vol. 240, Jan.-Mar. 1955, 954 Wavelength Range: 220 nm - 400 nm

Method: Direct absorption measurements, using long path lengths (up to 4.0 m). Only fair agreement with other studies. Insufficient technical information published to analyze method.

9) Plyler and Acquista, J.O.S.A., Vol. 44,1954, 505 Wavelength Range:

Method: Direct absorption measurements 30 μm, 10 μm, and 5 μm, pathlengths. However, large uncertainties in actual pathlengths of "10 μm" and "5 μm" cells, used Beer's law to determine these, based on 30 μm absorption values.

10) Pontier et Dechambenoy, Ann. Geophys., Vol. 22, 1966, 633 Wavelength Range: 1.0 μm - 40 μm

Method: Direct absorption measurements to yield some values of α, reflectance measurements to yield index of refraction, and also to yield α values in areas where α is large. Insufficient number of absorption measurements, and uncertainties in α values of up to 20% near absorption maxima, up to 50% for 3.0 μm band. α values systematically higher than other studies.

11) Querry, Curnutle and Williams, J.O.S.A., Vol.59, no. 10, Oct. 1969, 1299 Wavelength Range: 2.0 μm - 25.0 μm

Method: Reflectance study. Used α values from reference 6, Irvine and Pollack, except in 2.9 μm - 3.1 μm and 13.0 μm and 13.0 μm - 20.0 μm regions, where reflectance value was used to calculate α.

12) Robertson and Williams, J.O.S.A., Vol. 61, no. 10, Oct. 1971, 1316 Wavelength Range: 2.3 μm - 33.3 μm

Method: Direct absorption measurements, utilizing a wedge-shaped cell to obtain path lengths between 0 and 20 μm. Many measurements of % transmittance at each point; pathlengths determined by inter-

ference measurements.

13) Rush and Williams, J.O.S.A., Vol. 61, no. 7, July 1971, 895, Wavelength Range: 2.0 μm - 30.3 μm
Method: Used reflectance measurements and absorption coefficient values from previous studies to generate refractive index values, using Cauchy equation.

14) Tyler, Smith and Wilson, J.O.S.A., Vol. 62, no. 1, Jan. 1972, 83
Wavelength Range: 360 nm - 700 nm
Method: Reflectance study on "clear, natural water". Not in good agreement with reference 5, but did not use distilled water. Values not really relevant to present study.

15) Zolotarev, Mikhailov, Alperovich and Popov, Optics and Spectroscopy Vol. 27, 1969, 430 Wavelength Range: 1.0 μm - 10^6 μm
Method: Direct absorption measurements, internal reflection measurements, and reflectance studies to obtain α and n_r for peak values of absorption; Kramer-Kronig analysis to predict values at other points.

Table VII

Absorption Coefficients of Liquid Water

		U.M.	ref. 1	ref. 2	ref. 3	ref. 4	ref. 5	ref. 6	ref. 7	ref. 9
.200μ	α	7.0×10^{-2}	6.9×10^{-2}	8×10^{-2}	--	--	--	--	--	--
	N_r	(6.1-7.5)	1.396	1.424	--	--	--	--	--	--
.750μ	α	3.15×10^{-2}	2.6×10^{-2}	2.5×10^{-2}	--	--	--	--	8.9×10^{-2}	2.5×10^{-2}
	N_r	(1.7-3.3)	1.330	1.329	--	--	--	--	--	--
.800	α	2.36×10^{-2}	1.96×10^{-2}	2.1×10^{-2}	--	--	--	--	3.6×10^{-2}	2.05×10^{-2}
	N_r	(2.02-2.85)	1.329	1.328	--	--	--	--	--	--
.975	α	.483	.449	.46	--	--	--	--	.561	.46
	N_r	(.473-.490)	1.327	1.327	--	--	--	--	--	--
2.2	α	18.3	16.5	16	--	--	20.6	18.3	21	16
	N_r	(16.8-23.6)	1.296	1.293	1.290	--	1.288	1.278	--	--
3.8	α	127.4	112.4	111	165	113	177	113	127	--
	N_r	(116-136)	1.364	1.358	1.361	--	1.360	1.366	--	--
4.7	α	443.6	420	468	401	418	567	414	417	
	N_r	(425-461)	1.330	1.338	1.324	--	1.323	1.331	--	--
5.3	α	259.4	232	229	213	237	342	232	242	--
	N_r	(250-268	1.312	1.318	1.305	--	1.306	1.316	--	--
9.0	α	577	557	566	531	542	712	563	510	--
	N_r	(550-589)	1.262	1.269	1.261	--	1.255	1.252	--	--

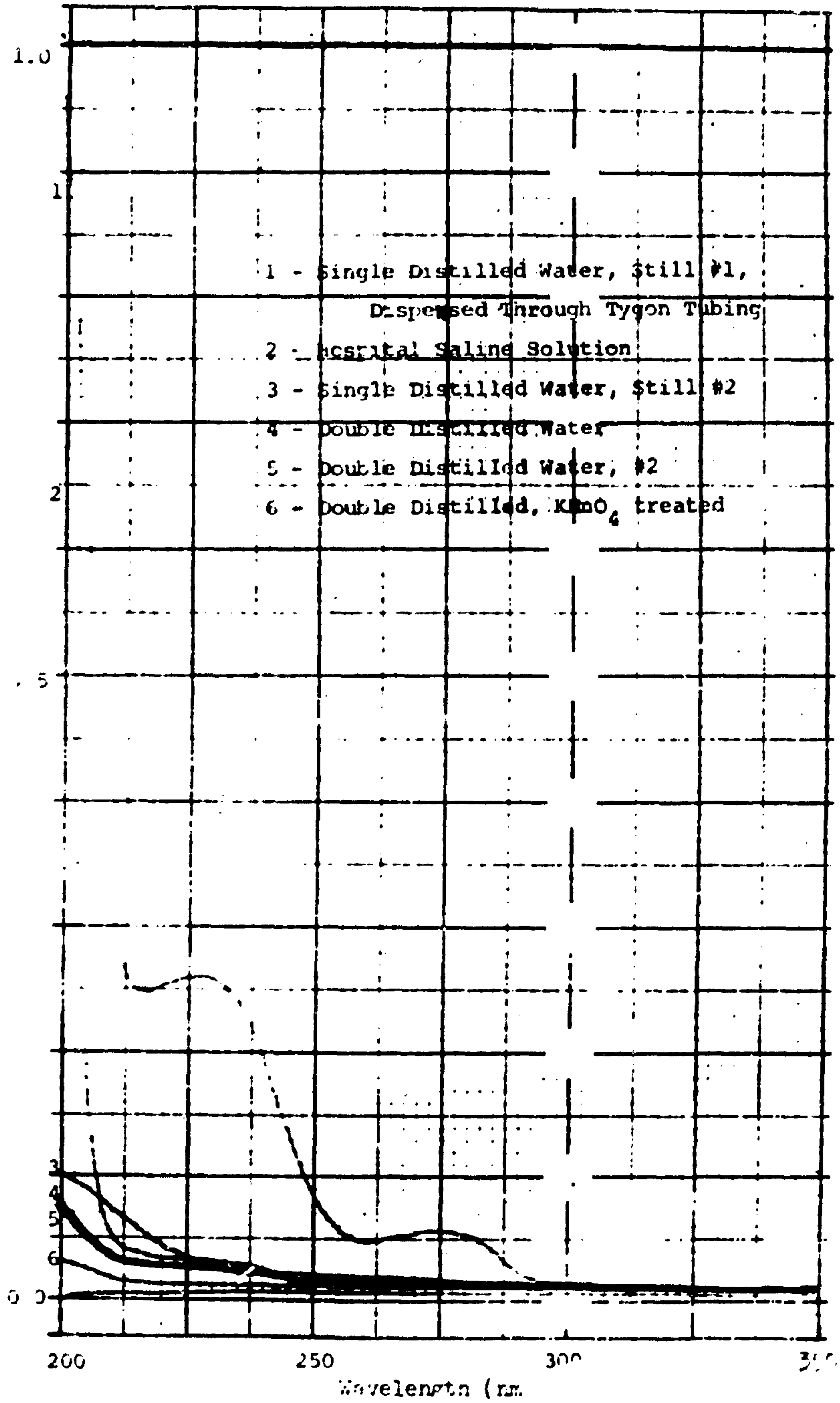


Figure 1-: Spectra of "Pure Water" and Saline Solution

APPENDIX III: FORTRAN STATEMENTS AND PROGRAM

A computer program was developed to convert the large amount of transmission data into absorbance and absorption coefficients. The mathematical development that preceded the programming is described in the section "EXPERIMENTAL PROCEDURE", subsection "Data Conversion Mathematics", starting on page 10.

Table VIII lists the Fortran statements and Table IX is a computer print-out of the program.

Table VIII: Fortran Statements

OPERATION	CORRESPONDING FORTRAN IV NAME OR EXPRESSION
A. Provide constants applicable to data being manipulated:	
b_m = optical pathlength of monkey eye component	b_m = BMONK
b_H = optical pathlength of corresponding human eye component	b_H = BHUMN
B. Store in the computer a table consisting of serially arranged wavelength values and corresponding spectrophotometer cell window and monkey eye component refractive index data:	
WAV (n) = tabular wavelength	WAV (n) = WAV (n)
n_1 (n) = refractive index of monkey eye component at a particular wavelength	n_1 (n) = RFEYE (n)
n_2 (n) = refractive index of spectrophotometer cell window at a particular wavelength	n_2 (n) = RFWIN (n)

Table VIII: (cont.)

C. Read the % Transmission of the monkey eye component determined experimentally at a particular wavelength.

Experimental wavelength = WAVLN
Experimental % T = TRANM

D. Search the stored wavelength table for refractive index data corresponding to the experimental wavelength in question. If an exact wavelength match does not occur, perform a linear interpolation on the refractive index data corresponding to the two nearest tabular wavelength values:

REYE = RFEYE(N-1)+(RFEYE(N)-RFEYE(N-1)*(WAVLN-WAV(N-1))/(WAV(N)-WAV(N-1))

RWIN = RFWIN(N-1)+(RFWIN(N)-RFWIN(N-1)*(WAVLN-WAV(N-1))/(WAV(N)-WAV(N-1)

$$\text{Interpolated } n_1=n_1(n-1)+\frac{[n_1(n)-n_1(n-1)][\text{WAVLN}-\text{WAV}(n-1)]}{\text{WAV}(n)-\text{WAV}(n-1)}$$

$$\text{Interpolated } n_2=n_2(n-1)+\frac{[n_2(n)-n_2(n-1)][\text{WAVLN}-\text{WAV}(n-1)]}{\text{WAV}(n)-\text{WAV}(n-1)}$$

E. Calculate the corrected % Transmission of the monkey eye component using appropriate refractive index data:

$$\%T\text{cor} = \frac{\text{Experimental } \% T}{\left(1-\left(\frac{n_1-n_2}{n_1+n_2}\right)^2\right)^2}$$

CTM = TRANM/((1-(((REYE-RWIN)/(REYE+RWIN))**2))**2)

F. Calculate the absorbance of the monkey eye component from %Tcor:

$$\text{Abs} = \log\frac{100}{\%T\text{cor}}$$

CAM = ALOG10(100./CTM)

G. Calculate the absorption coefficient of the monkey eye component:

$$\alpha = \frac{\ln\left(\frac{100}{\%T\text{cor}}\right)}{b_m}$$

ALPHA = (ALOG(100./CTM))/BMONK

Table VIII: (cont.)

H. Calculate the absorptivity of the monkey eye component:

$$a = \frac{Abs}{b_m}$$

ABSRP = CAM/BMONK

I. Calculate the absorbance of the corresponding human eye component:

$$Abs_H = (a)\ (b_H)$$

CAH = ABSRP*BHUMN

J. Calculate the %Transmission of the corresponding human eye component:

$$\%T_H = (100)\ 10^{-Abs_H}$$

CTH = 100.*(1./10**CAH)

```
      NCARD=34
      BMONK=.0516
      BHUMN=.0600
      KOUNT=0
      DIMENSION WAV(21),RFWIN(21),RFEYE(21)
      DO 2 N=1,21
      READ(5,4)WAV(N),RFWIN(N),RFEYE(N)
    2 CONTINUE
    4 FORMAT(F7.1,F6.3,F6.3)
    5 WRITE(6,6)
    6 FORMAT('1',////////,17X,'INPUT DATA IS DIRECT %TRANSMITTANCE DATA F
     1ROM CORNEA OF EYE OF RHESUS MONKEY')
      WRITE(6,7)
    7 FORMAT(///,23X,'UNCORRECTED',4X,'CORRECTED')
      WRITE(6,8)
    8 FORMAT(17X,'LAMBDA',8X,'% TRAN',8X,'% TRAN',6X,'ABSURBANCE',6X,'%
     1TRAN',6X,'ABSORBANCE',7X,'ALPHA',5X,'ABSORPTIVITY')
      WRITE(6,9)
    9 FORMAT(31X,'MONKEY',8X,'MONKEY',8X,'MONKEY', 9X,'HUMAN',9X,'HUMAN'
     1)
   10 N=1
      READ(5,12)WAVLN,TRANM
   12 FORMAT(F7.1,F6.2)
      IF(TRANM)13,13,14
   13 WRITE(6,15)WAVLN,TRANM
   15 FORMAT('0',15X,F7.1,8X,F6.2)
      GO TO 25
   14 IF(WAVLN-WAV(N))18,20,16
   16 N=N+1
      GO TO 14
   18 RWIN=RFWIN(N-1)+(RFWIN(N)-RFWIN(N-1))*(WAVLN-WAV(N-1))/(WAV(N)-WAV
     1(N-1))
      REYE=RFEYE(N-1)+(RFEYE(N)-RFEYE(N-1))*(WAVLN-WAV(N-1))/(WAV(N)-WAV
     1(N-1))
      GO TO 22
   20 RWIN=RFWIN(N)
      REYE=RFEYE(N)
   22 CTM=TRANM/(((1-(((REYE-RWIN)/(REYE+RWIN))**2))**2)
      CAM=ALOG10(100./CTM)
      ALPHA=(ALOG(100./CTM))/BMONK
      ABSRP=CAM/BMONK
      CAH=ABSRP*BHUMN
      IF(CAH-75.)31,32,32
   31 CTH=100.*(1./10**CAH)
      GO TO 33
```

Table IX: (cont.)

Fortran IV Program

```
0041        32   CTH=0.
0042        33   WRITE(6,24)WAVLN,TRANM,CTM,CAM,CTH,CAH,ALPHA,ABSRP
0043        24   FORMAT('0',15X,F7.1,8X,F6.2,8X,F6.2,8X,F6.3, 8X,F6.2,8X,F6.3,8X,F7
                1.2,7X,F6.2)
0044        25   KCUNT=KCUNT+1
0045             NCARD=NCARD-1
0046             IF(NCARD)30,30,26
0047        26   IF(KCUNT-19)10,28,28
0048        28   KOUNT=0
0049             GO TO 5
0050        30   CONTINUE
0051             END
   *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
   *OPTIONS IN EFFECT*  NAME = MAIN     , LINECNT =       57
   *STATISTICS*     SOURCE STATEMENTS =        51,PROGRAM SIZE =      1900
   *STATISTICS*  NO DIAGNOSTICS GENERATED
 NO ERRORS IN MAIN
```

APPENDIX IV: TRANSMISSION AND ABSORPTION DATA IN TABULAR FORM

Tables X through XIV are computer print-outs of transmission data taken from the master curves (Figures 13 through 18), tabulated every 10 nm except where the transmissions were changing rapidly, where 5 nm intervals were used. Also included in the print-outs are the additional data (absorption coefficients, absorbances, etc.) as described in the section "Data Handling", page 12.

The thickness constants used in these measurements and conversions were:

	Monkey	Human
Cornea	0.515 mm	0.6 mm
Aqueous	1.0 mm	3.0 mm
Lens	2.8 mm	3.2 mm

The data listed in the various columns of Tables X through XIV are as follows:

Column 1: The wavelengths in nanometers.

Column 2: The percent transmissions of the monkey ocular medium as taken from the master curve.

Column 3: The absorbance ($\log \frac{100}{\%T}$) of the monkey ocular medium at the thickness measured.

Column 4: The percent transmissions of the human ocular medium as calculated from Column 5.

Column 5: The absorbances ($\log \frac{100}{\%T}$) of human ocular medium as calculated from the corresponding monkey data and the above thickness values.

Column 6: The absorption coefficients, α (per cm^{-1}), as determined from column 7.

Column 7: The absorptivities, a (per cm^{-1}), as determined from the monkey ocular medium, using the thickness as measured (see above).

Table X

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
290.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
295.0	0.50	2.301	0.21	2.676	102.68	44.59
300.0	4.50	1.347	2.72	1.566	60.10	26.10
305.0	7.60	1.119	5.00	1.301	49.94	21.69
310.0	21.10	0.676	16.38	0.786	30.15	13.10
315.0	27.90	0.554	22.66	0.645	24.74	10.74
320.0	30.30	0.519	24.95	0.603	23.14	10.05
325.0	33.10	0.480	27.65	0.558	21.43	9.31
330.0	35.30	0.452	29.80	0.526	20.18	8.76
335.0	37.40	0.427	31.87	0.497	19.06	8.28
340.0	39.70	0.401	34.16	0.467	17.90	7.78
345.0	41.20	0.385	35.66	0.448	17.18	7.46
350.0	43.20	0.365	37.68	0.424	16.27	7.06
355.0	44.90	0.348	39.41	0.404	15.52	6.74
360.0	46.40	0.333	40.95	0.388	14.88	6.46
365.0	47.80	0.321	42.39	0.373	14.31	6.21
370.0	49.00	0.310	43.63	0.360	13.82	6.00
375.0	50.30	0.298	44.98	0.347	13.32	5.78
380.0	51.60	0.287	46.33	0.334	12.82	5.57

Table [illegible] (Cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
385.0	52.90	0.277	47.69	0.322	12.34	5.36
390.0	53.80	0.269	48.64	0.313	12.01	5.22
395.0	54.90	0.260	49.79	0.303	11.62	5.05
400.0	55.90	0.253	50.85	0.294	11.27	4.90
410.0	57.90	0.237	52.97	0.276	10.59	4.60
420.0	59.90	0.223	55.11	0.259	9.93	4.31
430.0	61.50	0.211	56.82	0.245	9.42	4.09
440.0	63.00	0.201	58.44	0.233	8.95	3.89
450.0	64.20	0.192	59.73	0.224	8.59	3.73
460.0	65.20	0.186	60.81	0.216	8.29	3.60
470.0	66.20	0.179	61.90	0.208	7.99	3.47
480.0	67.20	0.173	62.99	0.201	7.70	3.35
490.0	6[illegible].20	0.166	64.08	0.193	7.42	3.22
500.0	68.90	0.162	64.85	0.188	7.22	3.14
510.0	69.50	0.158	65.50	0.184	7.05	3.06
520.0	70.10	0.154	66.16	0.179	6.88	2.99
530.0	70.80	0.150	66.93	0.174	6.69	2.91
540.0	71.50	0.146	67.70	0.169	6.50	2.82
550.0	72.00	0.143	68.25	0.166	6.37	2.76

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
560.0	72.60	0.139	68.91	0.162	6.21	2.70
570.0	73.20	0.135	69.58	0.158	6.05	2.63
580.0	73.80	0.132	70.24	0.153	5.89	2.56
590.0	74.30	0.129	70.79	0.150	5.76	2.50
600.0	74.80	0.126	71.35	0.147	5.63	2.44
610.0	75.30	0.123	71.90	0.143	5.50	2.39
620.0	75.80	0.120	72.46	0.140	5.37	2.33
630.0	76.30	0.117	73.01	0.137	5.24	2.28
640.0	76.90	0.114	73.68	0.133	5.09	2.21
650.0	77.20	0.112	74.02	0.131	5.01	2.18
660.0	77.70	0.110	74.57	0.127	4.89	2.12
670.0	78.10	C.107	75.02	0.125	4.79	2.08
680.0	78.60	0.105	75.58	0.122	4.67	2.03
690.0	79.10	C.102	76.14	0.118	4.54	1.97
700.0	79.70	0.099	76.81	0.115	4.40	1.91
710.0	80.10	0.096	77.26	0.112	4.30	1.87
720.0	80.50	0.094	77.71	0.110	4.20	1.83
730.0	81.10	0.091	78.38	0.106	4.06	1.76
740.0	81.40	0.089	78.72	0.104	3.99	1.73

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
750.0	81.80	0.087	79.17	0.101	3.89	1.69
760.0	82.20	0.085	79.62	0.099	3.80	1.65
770.0	82.50	0.084	79.96	0.097	3.73	1.62
780.0	82.90	0.081	80.41	0.095	3.63	1.58
790.0	83.20	0.080	80.75	0.093	3.56	1.55
800.0	83.50	0.078	81.08	0.091	3.49	1.52
810.0	83.80	0.077	81.42	0.089	3.43	1.49
820.0	84.10	0.075	81.76	0.087	3.36	1.46
830.0	84.20	0.075	81.88	0.087	3.33	1.45
840.0	84.40	0.074	82.10	0.086	3.29	1.43
850.0	84.60	0.073	82.33	0.084	3.24	1.41
860.0	84.80	0.072	82.55	0.083	3.20	1.39
870.0	84.90	0.071	82.67	0.083	3.17	1.38
880.0	85.00	0.071	82.78	0.082	3.15	1.37
890.0	85.10	0.070	82.89	0.081	3.13	1.36
900.0	85.10	0.070	82.89	0.081	3.13	1.36
910.0	85.10	0.070	82.89	0.081	3.13	1.36
920.0	85.00	0.071	82.78	0.082	3.15	1.37
930.0	84.90	0.071	82.67	0.083	3.17	1.38

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
940.0	84.70	0.072	82.44	0.084	3.22	1.40
950.0	84.30	0.074	81.99	0.086	3.31	1.44
960.0	84.20	0.075	81.88	0.087	3.33	1.45
970.0	84.20	0.075	81.88	0.087	3.33	1.45
980.0	84.30	0.074	81.99	0.086	3.31	1.44
990.0	84.60	0.073	82.33	0.084	3.24	1.41
1000.0	84.90	0.071	82.67	0.083	3.17	1.38
1010.0	85.10	0.070	82.89	0.081	3.13	1.36
1020.0	85.30	0.069	83.12	0.080	3.08	1.34
1030.0	85.40	0.069	83.23	0.080	3.06	1.33
1040.0	85.50	0.068	83.35	0.079	3.04	1.32
1050.0	85.60	0.068	83.46	0.079	3.01	1.31
1060.0	85.70	0.067	83.57	0.078	2.99	1.30
1070.0	85.80	0.067	83.69	0.077	2.97	1.29
1080.0	85.80	0.067	83.69	0.077	2.97	1.29
1090.0	85.80	0.067	83.69	0.077	2.97	1.29
1100.0	85.70	0.067	83.57	0.078	2.99	1.30
1110.0	85.70	0.067	83.57	0.078	2.99	1.30
1120.0	85.60	0.068	83.46	0.079	3.01	1.31

Table X: (Cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1130.0	85.50	0.068	83.35	0.079	3.04	1.32
1140.0	85.30	0.069	83.12	0.080	3.08	1.34
1150.0	85.00	0.071	82.78	0.082	3.15	1.37
1160.0	84.80	0.072	82.55	0.083	3.20	1.39
1170.0	84.50	0.073	82.21	0.085	3.26	1.42
1180.0	84.40	0.074	82.10	0.086	3.29	1.43
1190.0	84.30	0.074	81.99	0.086	3.31	1.44
1200.0	84.50	0.073	82.21	0.085	3.26	1.42
1210.0	84.90	0.071	82.67	0.083	3.17	1.38
1220.0	85.30	0.069	83.12	0.080	3.08	1.34
1230.0	85.80	0.067	83.69	0.077	2.97	1.29
1240.0	86.10	0.065	84.03	0.076	2.90	1.26
1250.0	86.20	0.064	84.14	0.075	2.88	1.25
1260.0	86.10	0.065	84.03	0.076	2.90	1.26
1270.0	85.80	0.067	83.69	0.077	2.97	1.29
1280.0	85.30	0.069	83.12	0.080	3.08	1.34
1290.0	84.80	0.072	82.55	0.083	3.20	1.39
1300.0	83.90	0.076	81.54	0.089	3.40	1.48
1310.0	82.10	0.086	79.51	0.100	3.82	1.66

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1320.0	80.00	0.097	77.15	0.113	4.32	1.88
1330.0	77.10	0.113	73.90	0.131	5.04	2.19
1340.0	73.90	0.131	70.35	0.153	5.86	2.55
1350.0	70.00	0.155	66.05	0.180	6.91	3.00
1360.0	65.20	0.186	60.81	0.216	8.29	3.60
1370.0	61.00	0.215	56.28	0.250	9.58	4.16
1380.0	56.70	0.246	51.70	0.287	11.00	4.78
1390.0	50.00	0.301	44.66	0.350	13.43	5.83
1400.0	42.80	0.369	37.28	0.429	16.45	7.14
1410.0	34.50	0.462	29.01	0.537	20.62	8.96
1420.0	27.40	0.562	22.19	0.654	25.09	10.90
1430.0	24.80	0.606	19.76	0.704	27.02	11.74
1440.0	24.20	0.616	19.21	0.716	27.50	11.94
1450.0	24.10	0.618	19.12	0.719	27.58	11.98
1460.0	24.30	0.614	19.30	0.714	27.42	11.91
1470.0	25.60	0.592	20.51	0.688	26.41	11.47
1480.0	27.30	0.564	22.10	0.656	25.16	10.93
1490.0	29.70	0.527	24.37	0.613	23.53	10.22
1500.0	32.00	0.495	26.58	0.575	22.08	9.59

Table [illegible] (Cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSCRBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1510.0	35.00	0.456	29.50	0.530	20.35	8.84
1520.0	38.70	0.412	33.16	0.479	18.40	7.99
1530.0	42.20	0.375	36.67	0.436	16.72	7.26
1540.0	46.00	0.337	40.54	0.392	15.05	6.54
1550.0	49.50	0.305	44.15	0.355	13.63	5.92
1560.0	52.70	0.278	47.48	0.323	12.41	5.39
1570.0	55.60	0.255	50.53	0.296	11.38	4.94
1580.0	58.10	0.236	53.18	0.274	10.52	4.57
1590.0	61.00	0.215	56.28	0.250	9.58	4.16
1600.0	63.60	0.197	59.08	0.229	8.77	3.81
1610.0	65.70	0.182	61.36	0.212	8.14	3.54
1620.0	67.90	0.168	63.75	0.196	7.50	3.26
1630.0	69.80	0.156	65.83	0.182	6.97	3.03
1640.0	71.00	0.149	67.15	0.173	6.64	2.88
1650.0	72.90	0.137	69.24	0.160	6.13	2.66
1660.0	73.40	0.134	69.80	0.156	5.99	2.60
1670.0	73.70	0.133	70.13	0.154	5.91	2.57
1680.0	73.20	0.135	69.58	0.158	6.05	2.63
1690.0	72.30	0.141	68.58	0.164	6.29	2.73

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1700.0	70.00	0.155	66.05	0.180	6.91	3.00
1710.0	68.70	0.163	64.63	0.190	7.28	3.16
1720.0	67.20	0.173	62.99	0.201	7.70	3.35
1730.0	65.90	0.181	61.57	0.211	8.08	3.51
1740.0	64.20	0.192	59.73	0.224	8.59	3.73
1750.0	62.70	0.203	58.11	0.236	9.05	3.93
1760.0	60.80	0.216	56.07	0.251	9.64	4.19
1770.0	59.50	0.225	54.68	0.262	10.06	4.37
1780.0	58.90	0.230	54.04	0.267	10.26	4.46
1790.0	58.80	0.231	53.93	0.268	10.29	4.47
1800.0	58.90	0.230	54.04	0.267	10.26	4.46
1810.0	59.10	0.228	54.25	0.266	10.19	4.43
1820.0	59.30	0.227	54.46	0.264	10.13	4.40
1830.0	58.90	0.230	54.04	0.267	10.26	4.46
1840.0	56.90	0.245	51.91	0.285	10.93	4.75
1850.0	50.00	0.301	44.66	0.350	13.43	5.83
1860.0	40.30	0.395	34.76	0.459	17.61	7.65
1870.0	30.60	0.514	25.23	0.598	22.95	9.97
1880.0	20.90	0.680	16.20	0.791	30.34	13.18

[illegible]

[illegible] Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1890.0	11.30	0.947	7.92	1.101	42.26	18.35
1900.0	1.80	1.745	0.94	2.029	77.86	33.81
1910.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
1920.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
1930.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
1940.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
1950.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
1960.0	0.30	2.523	0.12	2.934	112.58	48.89
1970.0	0.70	2.155	0.31	2.506	96.16	41.76
1980.0	1.00	2.000	0.47	2.326	89.25	38.76
1990.0	1.30	1.886	0.64	2.193	84.16	36.55
2000.0	1.80	1.745	0.94	2.029	77.86	33.81
2010.0	2.40	1.620	1.31	1.883	72.28	31.39
2020.0	3.30	1.481	1.89	1.723	66.11	28.71
2030.0	4.50	1.347	2.72	1.566	60.10	26.10
2040.0	5.80	1.237	3.65	1.438	55.18	23.96
2050.0	7.50	1.125	4.92	1.308	50.20	21.80
2060.0	9.70	1.013	6.63	1.178	45.21	19.64
2070.0	12.00	0.921	8.50	1.071	41.09	17.85

Table X: (cont.

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2080.0	14.00	0.854	10.17	0.993	38.10	16.55
2090.0	16.80	0.775	12.57	0.901	34.57	15.01
2100.0	18.80	0.726	14.32	0.844	32.39	14.07
2110.0	20.70	0.684	16.02	0.795	30.52	13.26
2120.0	22.20	0.654	17.38	0.760	29.17	12.67
2130.0	23.70	0.625	18.75	0.727	27.90	12.12
2140.0	25.00	0.602	19.95	0.700	26.87	11.67
2150.0	25.90	0.587	20.79	0.682	26.18	11.37
2160.0	26.40	0.578	21.25	0.673	25.81	11.21
2170.0	26.90	0.570	21.72	0.663	25.45	11.05
2180.0	27.30	0.564	22.10	0.656	25.16	10.93
2190.0	28.00	0.553	22.76	0.643	24.67	10.71
2200.0	28.80	0.541	23.52	0.629	24.12	10.48
2210.0	29.50	0.530	24.18	0.616	23.66	10.27
2220.0	29.90	0.524	24.56	0.610	23.40	10.16
2230.0	29.10	0.536	23.80	0.623	23.92	10.39
2240.0	27.70	0.558	22.48	0.648	24.88	10.80
2250.0	25.90	0.587	20.79	0.682	26.18	11.37
2260.0	24.20	0.616	19.21	0.716	27.50	11.94

Table X: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSCRBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2270.0	23.00	0.638	18.11	0.742	28.48	12.37
2280.0	21.80	0.662	17.01	0.769	29.52	12.82
2290.0	20.70	0.684	16.02	0.795	30.52	13.26
2300.0	20.C0	C.699	15.39	0.813	31.19	13.55
2310.0	18.30	C.738	13.88	0.858	32.91	14.29
2320.0	17.00	0.770	12.74	0.895	34.34	14.91
2330.0	15.60	C.807	11.53	0.938	36.01	15.64
2340.0	14.00	0.854	10.17	0.993	38.10	16.55
2350.0	12.50	C.903	8.91	1.050	40.30	17.50
2360.0	10.90	0.963	7.60	1.119	42.95	18.65
2370.0	9.80	1.009	6.71	1.173	45.02	19.55
2380.0	8.50	1.071	5.69	1.245	47.77	20.75
2390.0	7.20	1.143	4.69	1.329	50.99	22.14
2400.0	6.20	1.208	3.94	1.404	53.89	23.40
2410.0	5.10	1.292	3.14	1.503	57.67	25.05
2420.0	4.30	1.367	2.58	1.589	60.98	26.48
2430.0	3.70	1.432	2.16	1.665	63.89	27.75
2440.0	2.90	1.538	1.63	1.788	68.61	29.80
2450.0	2.00	1.699	1.06	1.976	75.81	32.93

Table [illegible]: (cont.)

Direct Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2460.0	1.50	1.824	0.76	2.121	81.39	35.35
2470.0	1.00	2.000	0.47	2.326	89.25	38.76
2480.0	0.70	2.155	0.31	2.506	96.16	41.76
2490.0	0.30	2.523	0.12	2.934	112.58	48.89
2500.0	< 0.20	> 2.699	< 0.07	> 3.138	>120.44	> 52.31

Table VI

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
290.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31
295.0	0.50	2.301	0.21	2.676	102.68	44.59
300.0	4.50	1.347	2.72	1.566	60.10	26.10
305.0	7.60	1.119	5.00	1.301	49.94	21.69
310.0	29.80	0.526	24.47	0.611	23.46	10.19
315.0	42.00	0.377	36.67	0.438	16.81	7.30
320.0	47.70	0.321	42.28	0.374	14.35	6.23
325.0	52.00	0.284	46.75	0.330	12.67	5.50
330.0	56.00	0.252	50.96	0.293	11.24	4.88
335.0	58.70	0.231	53.82	0.269	10.32	4.48
340.0	61.20	0.213	56.50	0.248	9.52	4.13
345.0	63.90	0.194	59.41	0.226	8.68	3.77
350.0	66.00	0.180	61.68	0.210	8.05	3.50
355.0	68.30	0.166	64.19	0.193	7.39	3.21
360.0	70.50	0.152	66.60	0.177	6.77	2.94
365.0	72.80	0.138	69.13	0.160	6.15	2.67
370.0	74.70	0.127	71.24	0.147	5.65	2.46
375.0	76.10	0.119	72.79	0.138	5.29	2.30
380.0	77.20	0.112	74.02	0.131	5.01	2.18

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
385.0	78.20	0.107	75.13	0.124	4.77	2.07
390.0	79.10	0.102	76.14	0.118	4.54	1.97
395.0	80.70	0.093	77.93	0.108	4.16	1.80
400.0	81.90	0.087	79.28	0.101	3.87	1.68
410.0	83.00	0.081	80.52	0.094	3.61	1.57
420.0	85.00	0.071	82.78	0.082	3.15	1.37
430.0	87.00	0.060	85.05	0.070	2.70	1.17
440.0	88.50	0.053	86.76	0.062	2.37	1.03
450.0	89.60	0.048	88.01	0.055	2.13	0.92
460.0	90.20	0.045	88.70	0.052	2.00	0.87
470.0	90.80	0.042	89.38	0.049	1.87	0.81
480.0	91.10	0.040	89.73	0.047	1.81	0.78
490.0	91.60	0.038	90.30	0.044	1.70	0.74
500.0	92.10	0.036	90.87	0.042	1.59	0.69
510.0	92.70	0.033	91.56	0.038	1.47	0.64
520.0	93.00	0.032	91.91	0.037	1.41	0.61
530.0	93.40	0.030	92.37	0.034	1.32	0.57
540.0	93.90	0.027	92.94	0.032	1.22	0.53
550.0	94.20	0.026	93.29	0.030	1.16	0.50

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
560.0	94.60	0.024	93.75	0.028	1.08	0.47
570.0	94.80	0.023	93.98	0.027	1.03	0.45
580.0	95.00	0.022	94.21	0.026	0.99	0.43
590.0	95.10	0.022	94.33	0.025	0.97	0.42
600.0	95.30	0.021	94.56	0.024	0.93	0.41
610.0	95.40	0.020	94.67	0.024	0.91	0.40
620.0	95.70	0.019	95.02	0.022	0.85	0.37
630.0	95.80	0.019	95.13	0.022	0.83	0.36
640.0	95.90	0.018	95.25	0.021	0.81	0.35
650.0	96.00	0.018	95.36	0.021	0.79	0.34
660.0	96.00	0.018	95.36	0.021	0.79	0.34
670.0	96.20	0.017	95.60	0.020	0.75	0.33
680.0	96.20	0.017	95.60	0.020	0.75	0.33
690.0	96.40	0.016	95.83	0.019	0.71	0.31
700.0	96.70	0.015	96.17	0.017	0.65	0.28
710.0	96.80	0.014	96.29	0.016	0.63	0.27
720.0	96.80	0.014	96.29	0.016	0.63	0.27
730.0	96.90	0.014	96.40	0.016	0.61	0.27
740.0	96.90	0.014	96.40	0.016	0.61	0.27

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSCRBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
750.0	96.90	0.014	96.40	0.016	0.61	0.27
760.0	97.00	0.013	96.52	0.015	0.59	0.26
770.0	97.00	0.013	96.52	0.015	0.59	0.26
780.0	97.00	0.013	96.52	0.015	0.59	0.26
790.0	97.00	0.013	96.52	0.015	0.59	0.26
800.0	97.00	0.013	96.52	0.015	0.59	0.26
810.0	97.00	0.013	96.52	0.015	0.59	0.26
820.0	97.00	0.013	96.52	0.015	0.59	0.26
830.0	97.00	0.013	96.52	0.015	0.59	0.26
840.0	97.00	0.013	96.52	0.015	0.59	0.26
850.0	97.10	0.013	96.64	0.015	0.57	0.25
860.0	97.10	0.013	96.64	0.015	0.57	0.25
870.0	97.20	0.012	96.75	0.014	0.55	0.24
880.0	97.20	0.012	96.75	0.014	0.55	0.24
890.0	97.20	0.012	96.75	0.014	0.55	0.24
900.0	97.20	0.012	96.75	0.014	0.55	0.24
910.0	97.10	0.013	96.64	0.015	0.57	0.25
920.0	96.80	0.014	96.29	0.016	0.63	0.27
930.0	96.40	0.016	95.83	0.019	0.71	0.31

Table XI (Cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
940.0	96.20	0.017	95.60	0.020	0.75	0.33
950.0	96.10	0.017	95.48	0.020	0.77	0.33
960.0	96.00	0.018	95.36	0.021	0.79	0.34
970.0	96.00	0.018	95.36	0.021	0.79	0.34
980.0	96.00	0.018	95.36	0.021	0.79	0.34
990.0	96.20	0.017	95.60	0.020	0.75	0.33
1000.0	96.50	0.015	95.94	0.018	0.69	0.30
1010.0	96.80	0.014	96.29	0.016	0.63	0.27
1020.0	96.90	0.014	96.40	0.016	0.61	0.27
1030.0	97.00	0.013	96.52	0.015	0.59	0.26
1040.0	97.10	0.013	96.64	0.015	0.57	0.25
1050.0	97.20	0.012	96.75	0.014	0.55	0.24
1060.0	97.20	0.012	96.75	0.014	0.55	0.24
1070.0	97.20	0.012	96.75	0.014	0.55	0.24
1080.0	97.20	0.012	96.75	0.014	0.55	0.24
1090.0	97.20	0.012	96.75	0.014	0.55	0.24
1100.0	97.20	0.012	96.75	0.014	0.55	0.24
1110.0	97.20	0.012	96.75	0.014	0.55	0.24
1120.0	97.20	0.012	96.75	0.014	0.55	0.24

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1130.0	97.10	0.013	96.64	0.015	0.57	0.25
1140.0	97.00	0.013	96.52	0.015	0.59	0.26
1150.0	97.00	0.013	96.52	0.015	0.59	0.26
1160.0	96.80	0.014	96.29	0.016	0.63	0.27
1170.0	96.60	0.015	96.06	0.017	0.67	0.29
1180.0	96.40	0.016	95.83	0.019	0.71	0.31
1190.0	96.30	0.016	95.71	0.019	0.73	0.32
1200.0	96.40	0.016	95.83	0.019	0.71	0.31
1210.0	96.80	0.014	96.29	0.016	0.63	0.27
1220.0	97.20	0.012	96.75	0.014	0.55	0.24
1230.0	97.50	0.011	97.10	0.013	0.49	0.21
1240.0	97.70	0.010	97.33	0.012	0.45	0.20
1250.0	97.70	0.010	97.33	0.012	0.45	0.20
1260.0	97.60	0.011	97.21	0.012	0.47	0.20
1270.0	97.10	0.013	96.64	0.015	0.57	0.25
1280.0	96.20	0.017	95.60	0.020	0.75	0.33
1290.0	95.20	0.021	94.44	0.025	0.95	0.41
1300.0	93.90	0.027	92.94	0.032	1.22	0.53
1310.0	92.00	0.036	90.76	0.042	1.62	0.70

Table A1: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1320.0	90.10	0.045	88.58	0.053	2.02	0.88
1330.0	87.60	0.057	85.73	0.067	2.57	1.11
1340.0	85.00	0.071	82.78	0.082	3.15	1.37
1350.0	82.00	0.086	79.39	0.100	3.85	1.67
1360.0	78.80	0.103	75.80	0.120	4.62	2.01
1370.0	74.80	0.126	71.35	0.147	5.63	2.44
1380.0	69.00	0.161	64.96	0.187	7.19	3.12
1390.0	64.00	0.194	59.52	0.225	8.65	3.76
1400.0	56.20	0.250	51.17	0.291	11.17	4.85
1410.0	46.60	0.332	41.15	0.386	14.80	6.43
1420.0	36.80	0.434	31.27	0.505	19.37	8.41
1430.0	29.50	0.530	24.18	0.616	23.66	10.27
1440.0	26.80	0.572	21.63	0.665	25.52	11.08
1450.0	26.60	0.575	21.44	0.669	25.66	11.15
1460.0	27.00	0.569	21.82	0.661	25.37	11.02
1470.0	28.10	0.551	22.85	0.641	24.60	10.68
1480.0	30.00	0.523	24.66	0.608	23.33	10.13
1490.0	32.10	0.493	26.68	0.574	22.02	9.56
1500.0	35.20	0.453	29.70	0.527	20.2[illegible]	8.79

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1510.0	38.70	0.412	33.16	0.479	18.40	7.99
1520.0	42.10	0.376	36.57	0.437	16.77	7.28
1530.0	46.30	0.334	40.85	0.389	14.92	6.48
1540.0	49.90	0.302	44.56	0.351	13.47	5.85
1550.0	53.10	0.275	47.90	0.320	12.27	5.33
1560.0	56.50	0.248	51.49	0.288	11.06	4.81
1570.0	60.00	0.222	55.21	0.258	9.90	4.30
1580.0	62.90	0.201	58.33	0.234	8.98	3.90
1590.0	66.00	0.180	61.68	0.210	8.05	3.50
1600.0	68.90	0.162	64.85	0.188	7.22	3.14
1610.0	71.20	0.148	67.37	0.172	6.58	2.86
1620.0	73.60	0.133	70.02	0.155	5.94	2.58
1630.0	75.40	0.123	72.01	0.143	5.47	2.38
1640.0	76.90	0.114	73.68	0.133	5.09	2.21
1650.0	78.10	0.107	75.02	0.125	4.79	2.08
1660.0	78.60	0.105	75.58	0.122	4.67	2.03
1670.0	78.60	0.105	75.58	0.122	4.67	2.03
1680.0	78.10	0.107	75.02	0.125	4.79	2.08
1690.0	77.00	0.114	73.79	0.132	5.07	2.20

Table XII (Cont.)

Total Transmittance and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1700.0	75.80	0.120	72.46	0.140	5.37	2.33
1710.0	74.30	0.129	70.79	0.150	5.76	2.50
1720.0	72.80	0.138	69.13	0.160	6.15	2.67
1730.0	71.10	0.148	67.26	0.172	6.61	2.87
1740.0	69.40	0.159	65.39	0.184	7.08	3.07
1750.0	67.50	0.171	63.32	0.198	7.62	3.31
1760.0	65.80	0.182	61.47	0.211	8.11	3.52
1770.0	64.70	0.189	60.27	0.220	8.44	3.66
1780.0	64.00	0.194	59.52	0.225	8.65	3.76
1790.0	64.00	0.194	59.52	0.225	8.65	3.76
1800.0	64.00	0.194	59.52	0.225	8.65	3.76
1810.0	64.20	0.192	59.73	0.224	8.59	3.73
1820.0	64.30	0.192	59.84	0.223	8.56	3.72
1830.0	63.80	0.195	59.30	0.227	8.71	3.78
1840.0	61.20	0.213	56.50	0.248	9.52	4.13
1850.0	54.80	0.261	49.69	0.304	11.66	5.06
1860.0	45.00	0.347	39.51	0.403	15.47	6.72
1870.0	36.50	0.438	30.98	0.509	19.53	8.48
1880.0	24.80	0.606	19.76	0.704	27.02	11.74

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1890.0	14.40	0.842	10.50	0.979	37.56	16.31
1900.0	3.00	1.523	1.70	1.771	67.96	29.51
1910.0	0.20	2.699	0.07	3.138	120.44	52.31
1920.0	0.20	2.699	0.07	3.138	120.44	52.31
1930.0	0.20	2.699	0.07	3.138	120.44	52.31
1940.0	0.20	2.699	0.07	3.138	120.44	52.31
1950.0	0.30	2.523	0.12	2.934	112.58	48.89
1960.0	0.50	2.301	0.21	2.676	102.68	44.59
1970.0	0.80	2.097	0.36	2.438	93.57	40.64
1980.0	1.10	1.959	0.53	2.277	87.40	37.96
1990.0	1.60	1.796	0.82	2.088	80.14	34.80
2000.0	2.20	1.658	1.18	1.927	73.97	32.12
2010.0	3.30	1.481	1.89	1.723	66.11	28.71
2020.0	4.80	1.319	2.93	1.533	58.85	25.56
2030.0	6.80	1.167	4.39	1.358	52.10	22.63
2040.0	9.00	1.046	6.08	1.216	46.67	20.27
2050.0	11.90	0.924	8.42	1.075	41.25	17.92
2060.0	14.80	0.830	10.84	0.965	37.03	16.08
2070.0	17.80	0.750	13.44	0.872	33.45	14.53

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2080.0	20.10	0.697	15.48	0.810	31.09	13.50
2090.0	22.80	0.642	17.92	0.747	28.65	12.44
2100.0	24.80	0.606	19.76	0.704	27.02	11.74
2110.0	26.50	0.577	21.35	0.671	25.74	11.10
2120.0	28.00	0.553	22.76	0.643	24.67	10.71
2130.0	29.20	0.535	23.90	0.622	23.86	10.36
2140.0	30.10	0.521	24.76	0.606	23.27	10.11
2150.0	31.10	0.507	25.72	0.590	22.63	9.83
2160.0	31.70	0.499	26.29	0.580	22.26	9.67
2170.0	31.90	0.496	26.49	0.577	22.14	9.62
2180.0	32.40	0.489	26.97	0.569	21.84	9.49
2190.0	33.10	0.480	27.65	0.558	21.43	9.31
2200.0	34.10	0.467	28.62	0.543	20.85	9.06
2210.0	35.20	0.453	29.70	0.527	20.23	8.79
2220.0	35.80	0.446	30.29	0.519	19.91	8.65
2230.0	35.70	0.447	30.19	0.520	19.96	8.67
2240.0	34.20	0.466	28.72	0.542	20.79	9.03
2250.0	32.00	0.495	26.58	0.575	22.08	9.59
2260.0	30.10	0.521	24.76	0.606	23.27	10.11

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2270.0	28.50	0.545	23.23	0.634	24.33	10.57
2280.0	26.80	0.572	21.63	0.665	25.52	11.08
2290.0	25.00	0.602	19.95	0.700	26.87	11.67
2300.0	23.90	0.622	18.93	0.723	27.74	12.05
2310.0	22.20	0.654	17.38	0.760	29.17	12.67
2320.0	20.40	0.690	15.75	0.803	30.81	13.38
2330.0	19.00	0.721	14.50	0.839	32.18	13.98
2340.0	17.50	0.757	13.18	0.880	33.78	14.67
2350.0	16.10	0.793	11.96	0.922	35.39	15.37
2360.0	15.00	0.824	11.01	0.958	36.77	15.97
2370.0	13.60	0.866	9.83	1.008	38.66	16.79
2380.0	12.00	0.921	8.50	1.071	41.09	17.85
2390.0	10.50	0.979	7.28	1.138	43.68	18.97
2400.0	9.50	1.022	6.48	1.189	45.62	19.81
2410.0	8.00	1.097	5.30	1.275	48.95	21.26
2420.0	6.90	1.161	4.47	1.350	51.81	22.50
2430.0	5.60	1.252	3.50	1.456	55.86	24.26
2440.0	4.30	1.367	2.58	1.589	60.98	26.48
2450.0	3.10	1.509	1.76	1.754	67.32	29.24

Table XI: (cont.)

Total Transmission and Absorption Data of the Cornea

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2460.0	2.10	1.678	1.12	1.951	74.87	32.52
2470.0	1.40	1.854	0.70	2.156	82.73	35.93
2480.0	0.90	2.046	0.42	2.379	91.29	39.65
2490.0	0.50	2.301	0.21	2.676	102.68	44.59
2500.0	0.30	2.523	0.12	2.934	112.58	48.89
2510.0	<0.20	>2.699	<0.07	>3.138	>120.44	>52.31

Table XII

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
195.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99
200.0	0.40	2.398	0.00	7.194	55.21	23.98
205.0	1.30	1.886	0.00	5.658	43.43	18.86
210.0	7.10	1.149	0.04	3.446	26.45	11.49
215.0	13.00	0.886	0.22	2.658	20.40	8.86
220.0	18.90	0.724	0.68	2.171	16.66	7.24
225.0	22.00	0.658	1.06	1.973	15.14	6.58
230.0	24.80	0.606	1.53	1.817	13.94	6.06
235.0	23.00	0.638	1.22	1.915	14.70	6.38
240.0	16.00	0.796	0.41	2.388	18.33	7.96
245.0	10.00	1.000	0.10	3.000	23.03	10.00
250.0	5.00	1.301	0.01	3.903	29.96	13.01
255.0	2.20	1.658	0.00	4.973	38.17	16.58
260.0	1.10	1.959	0.00	5.876	45.10	19.59
265.0	1.00	2.000	0.00	6.000	46.05	20.00
270.0	1.50	1.824	0.00	5.472	42.00	18.24
275.0	3.10	1.509	0.00	4.526	34.74	15.09
280.0	5.90	1.229	0.02	3.687	28.30	12.29
285.0	13.00	0.886	0.22	2.658	20.40	8.86

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
290.0	33.90	0.470	3.90	1.409	10.82	4.70
295.0	55.00	0.260	16.64	0.779	5.98	2.60
300.0	71.10	0.148	35.94	0.444	3.41	1.48
305.0	87.00	0.060	65.85	0.181	1.39	0.60
310.0	93.50	0.029	81.74	0.088	0.67	0.29
315.0	95.00	0.022	85.74	0.067	0.51	0.22
320.0	95.60	0.020	87.37	0.059	0.45	0.20
325.0	96.10	0.017	88.75	0.052	0.40	0.17
330.0	96.30	0.016	89.31	0.049	0.38	0.16
335.0	96.50	0.015	89.86	0.046	0.36	0.15
340.0	96.60	0.015	90.14	0.045	0.35	0.15
345.0	96.80	0.014	90.70	0.042	0.33	0.14
350.0	97.00	0.013	91.27	0.040	0.30	0.13
360.0	97.20	0.012	91.83	0.037	0.28	0.12
370.0	97.40	0.011	92.40	0.034	0.26	0.11
380.0	97.60	0.011	92.97	0.032	0.24	0.11
390.0	97.80	0.010	93.54	0.029	0.22	0.10
400.0	98.00	0.009	94.12	0.026	0.20	0.09
410.0	98.10	0.008	94.41	0.025	0.19	0.08

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
420.0	98.20	0.008	94.70	0.024	0.18	0.08
430.0	98.40	0.007	95.28	0.021	0.16	0.07
440.0	98.50	0.007	95.57	0.020	0.15	0.07
450.0	98.60	0.006	95.86	0.018	0.14	0.06
460.0	98.80	0.005	96.44	0.016	0.12	0.05
470.0	98.80	0.005	96.44	0.016	0.12	0.05
480.0	98.90	0.005	96.74	0.014	0.11	0.05
490.0	99.00	0.004	97.03	0.013	0.10	0.04
500.0	99.00	0.004	97.03	0.013	0.10	0.04
510.0	99.00	0.004	97.03	0.013	0.10	0.04
520.0	99.00	0.004	97.03	0.013	0.10	0.04
530.0	99.10	0.004	97.32	0.012	0.09	0.04
540.0	99.10	0.004	97.32	0.012	0.09	0.04
550.0	99.10	0.004	97.32	0.012	0.09	0.04
560.0	99.10	0.004	97.32	0.012	0.09	0.04
570.0	99.10	0.004	97.32	0.012	0.09	0.04
580.0	99.10	0.004	97.32	0.012	0.09	0.04
590.0	99.10	0.004	97.32	0.012	0.09	0.04
600.0	99.10	0.004	97.32	0.012	0.09	0.04

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
610.0	99.10	0.004	97.32	0.012	0.09	0.04
620.0	99.10	0.004	97.32	0.012	0.09	0.04
630.0	99.20	0.003	97.62	0.010	0.08	0.03
640.0	99.20	0.003	97.62	0.010	0.08	0.03
650.0	99.20	0.003	97.62	0.010	0.08	0.03
660.0	99.20	0.003	97.62	0.010	0.08	0.03
670.0	99.20	0.003	97.62	0.010	0.08	0.03
680.0	99.50	0.002	98.51	0.007	0.05	0.02
690.0	99.50	0.002	98.51	0.007	0.05	0.02
700.0	99.50	0.002	98.51	0.007	0.05	0.02
710.0	99.50	0.002	98.51	0.007	0.05	0.02
720.0	99.50	0.002	98.51	0.007	0.05	0.02
730.0	99.50	0.002	98.51	0.007	0.05	0.02
740.0	99.40	0.003	98.21	0.008	0.06	0.03
750.0	99.50	0.002	98.51	0.007	0.05	0.02
760.0	99.50	0.002	98.51	0.007	0.05	0.02
770.0	99.50	0.002	98.51	0.007	0.05	0.02
780.0	99.40	0.003	98.21	0.008	0.06	0.03
790.0	99.40	0.003	98.21	0.008	0.06	0.03

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
800.0	99.50	0.002	98.51	0.007	0.05	0.02
810.0	99.50	0.002	98.51	0.007	0.05	0.02
820.0	99.50	0.002	98.51	0.007	0.05	0.02
830.0	99.50	0.002	98.51	0.007	0.05	0.02
840.0	99.50	0.002	98.51	0.007	0.05	0.02
850.0	99.50	0.002	98.51	0.007	0.05	0.02
860.0	99.50	0.002	98.51	0.007	0.05	0.02
870.0	99.40	0.003	98.21	0.008	0.06	0.03
880.0	99.20	0.003	97.62	0.010	0.08	0.03
890.0	99.20	0.003	97.62	0.010	0.08	0.03
900.0	99.00	0.004	97.03	0.013	0.10	0.04
910.0	98.80	0.005	96.44	0.016	0.12	0.05
920.0	98.60	0.006	95.86	0.018	0.14	0.06
930.0	98.10	0.008	94.41	0.025	0.19	0.08
940.0	97.30	0.012	92.12	0.036	0.27	0.12
950.0	96.70	0.015	90.42	0.044	0.34	0.15
960.0	95.80	0.019	87.92	0.056	0.43	0.19
970.0	95.10	0.022	86.01	0.065	0.50	0.22
980.0	95.00	0.022	85.74	0.067	0.51	0.22

Table XII: (Cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
990.0	95.10	0.022	86.01	0.065	0.50	0.22
1000.0	95.50	0.020	87.10	0.060	0.46	0.20
1010.0	95.80	0.019	87.92	0.056	0.43	0.19
1020.0	96.10	0.017	88.75	0.052	0.40	0.17
1030.0	96.50	0.015	89.86	0.046	0.36	0.15
1040.0	96.90	0.014	90.99	0.041	0.31	0.14
1050.0	97.10	0.013	91.55	0.038	0.29	0.13
1060.0	97.20	0.012	91.83	0.037	0.28	0.12
1070.0	97.30	0.012	92.12	0.036	0.27	0.12
1080.0	97.40	0.011	92.40	0.034	0.26	0.11
1090.0	97.30	0.012	92.12	0.036	0.27	0.12
1100.0	97.20	0.012	91.83	0.037	0.28	0.12
1110.0	96.70	0.015	90.42	0.044	0.34	0.15
1120.0	95.20	0.021	86.28	0.064	0.49	0.21
1130.0	93.80	0.028	82.53	0.083	0.64	0.28
1140.0	92.10	0.036	78.12	0.107	0.82	0.36
1150.0	90.20	0.045	73.39	0.134	1.03	0.45
1160.0	88.90	0.051	70.26	0.153	1.18	0.51
1170.0	87.60	0.057	67.22	0.172	1.32	0.57

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1180.0	86.70	0.062	65.17	0.186	1.43	0.62
1190.0	86.40	0.063	64.50	0.190	1.46	0.63
1200.0	86.50	0.063	64.72	0.189	1.45	0.63
1210.0	86.70	0.062	65.17	0.186	1.43	0.62
1220.0	86.90	0.061	65.62	0.183	1.40	0.61
1230.0	87.20	0.059	66.31	0.178	1.37	0.59
1240.0	87.60	0.057	67.22	0.172	1.32	0.57
1250.0	87.80	0.057	67.68	0.170	1.30	0.57
1260.0	88.00	0.056	68.15	0.167	1.28	0.56
1270.0	88.00	0.056	68.15	0.167	1.28	0.56
1280.0	88.00	0.056	68.15	0.167	1.28	0.56
1290.0	87.80	0.057	67.68	0.170	1.30	0.57
1300.0	87.00	0.060	65.85	0.181	1.39	0.60
1310.0	85.90	0.066	63.38	0.198	1.52	0.66
1320.0	83.30	0.079	57.80	0.238	1.83	0.79
1330.0	81.60	0.088	54.33	0.265	2.03	0.88
1340.0	77.20	0.112	46.01	0.337	2.59	1.12
1350.0	72.00	0.143	37.32	0.428	3.29	1.43
1360.0	67.00	0.174	30.08	0.522	4.00	1.74

Table XIII (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1370.0	61.60	0.210	23.37	0.631	4.85	2.10
1380.0	55.30	0.257	16.91	0.772	5.92	2.57
1390.0	43.80	0.359	8.40	1.076	8.26	3.59
1400.0	25.90	0.587	1.74	1.760	13.51	5.87
1410.0	11.50	0.939	0.15	2.818	21.63	9.39
1420.0	5.10	1.292	0.03	3.877	29.76	12.92
1430.0	3.20	1.495	0.0[illegible]	4.485	34.42	14.95
1440.0	2.70	1.569	0.00	4.706	36.12	15.69
1450.0	2.70	1.569	0.00	4.706	36.12	15.69
1460.0	2.80	1.553	0.00	4.659	35.76	15.53
1470.0	3.20	1.495	0.00	4.485	34.42	14.95
1480.0	4.20	1.377	0.01	4.130	31.70	13.77
1490.0	6.00	1.222	0.02	3.666	28.13	12.22
1500.0	8.40	1.076	0.06	3.227	[illegible]	10.76
1510.0	10.80	0.967	0.13	2.900	22.28	9.67
1520.0	13.90	0.857	0.27	2.571	19.73	8.57
1530.0	8.00	0.745	0.58	2.234	17.15	7.45
1540.0	22.30	0.652	1.11	1.955	15.01	6.52
1550.0	27.40	0.562	2.06	1.687	12.95	5.62

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1560.0	31.70	0.499	3.19	1.497	11.49	4.99
1570.0	35.10	0.455	4.32	1.364	10.47	4.55
1580.0	38.90	0.410	5.89	1.230	9.44	4.10
1590.0	41.80	0.379	7.30	1.136	8.72	3.79
1600.0	44.10	0.356	8.53	1.067	8.19	3.56
1610.0	46.10	0.336	9.80	1.009	7.74	3.36
1620.0	47.90	0.320	10.99	0.959	7.36	3.20
1630.0	49.60	0.305	12.20	0.914	7.01	3.05
1640.0	50.90	0.293	13.19	0.880	6.75	2.93
1650.0	52.10	0.283	14.14	0.849	6.52	2.83
1660.0	53.20	0.274	15.06	0.822	6.31	2.74
1670.0	54.20	0.266	15.92	0.798	6.12	2.66
1680.0	54.80	0.261	16.46	0.784	6.01	2.61
1690.0	55.00	0.260	16.64	0.779	5.98	2.60
1700.0	55.00	0.260	16.64	0.779	5.98	2.60
1710.0	54.90	0.260	16.55	0.781	6.00	2.60
1720.0	54.30	0.265	16.01	0.796	6.11	2.65
1730.0	53.20	0.274	15.06	0.822	6.31	2.74
1740.0	51.80	0.286	13.90	0.857	6.58	2.86

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1750.0	49.90	0.302	12.43	0.906	6.95	3.02
1760.0	48.00	0.319	11.06	0.956	7.34	3.19
1770.0	45.30	0.344	9.30	1.032	7.92	3.44
1780.0	43.00	0.367	7.95	1.100	8.44	3.67
1790.0	40.20	0.396	6.50	1.187	9.11	3.96
1800.0	38.10	0.419	5.53	1.257	9.65	4.19
1810.0	37.80	0.423	5.40	1.268	9.73	4.23
1820.0	37.20	0.429	5.15	1.288	9.89	4.29
1830.0	36.50	0.438	4.86	1.313	10.08	4.38
1840.0	35.20	0.453	4.36	1.360	10.44	4.53
1850.0	32.70	0.485	3.50	1.456	11.18	4.85
1860.0	27.00	0.569	1.97	1.706	13.09	5.69
1870.0	15.30	0.315	0.36	2.446	18.77	8.15
1880.0	2.50	1.602	0.00	4.806	36.89	16.02
1890.0	0.40	2.398	0.00	7.194	55.21	23.98
1900.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99
1910.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99
1920.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99
1930.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1940.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	>26.99
1950.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
1960.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
1970.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
1980.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
1990.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
2000.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
2010.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
2020.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
2030.0	< 0.20	> 2.699	0.00	> 8.097	> 62.15	> 26.99
2040.0	0.20	2.699	0.00	8.097	62.15	26.99
2050.0	0.50	2.301	0.00	6.903	52.98	23.01
2060.0	0.80	2.097	0.00	6.291	48.28	20.97
2070.0	1.20	1.921	0.00	5.762	44.23	19.21
2080.0	1.80	1.745	0.00	5.234	40.17	17.45
2090.0	2.70	1.569	0.00	4.706	36.12	15.69
2100.0	3.60	1.444	0.00	4.331	33.24	14.44
2110.0	4.30	1.367	0.01	4.100	31.47	13.67
2120.0	5.30	1.276	0.01	3.827	29.37	12.76

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2130.0	6.60	1.180	0.03	3.541	27.18	11.80
2140.0	7.80	1.108	0.05	3.324	25.51	11.08
2150.0	8.90	1.051	0.07	3.152	24.19	10.51
2160.0	9.80	1.009	0.09	3.026	23.23	10.09
2170.0	10.70	0.971	0.12	2.912	22.35	9.71
2180.0	11.20	0.951	0.14	2.852	21.89	9.51
2190.0	11.80	0.928	0.16	2.784	21.37	9.28
2200.0	12.00	0.921	0.17	2.762	21.20	9.21
2210.0	12.20	0.914	0.18	2.741	21.04	9.14
2220.0	12.20	0.914	0.18	2.741	21.04	9.14
2230.0	12.10	0.917	0.18	2.752	21.12	9.17
2240.0	11.80	0.928	0.16	2.784	21.37	9.28
2250.0	11.20	0.951	0.14	2.852	21.89	9.51
2260.0	10.40	0.983	0.11	2.949	22.63	9.83
2270.0	9.70	1.013	0.09	3.040	23.33	10.13
2280.0	8.40	1.076	0.06	3.227	24.77	10.76
2290.0	7.20	1.143	0.04	3.428	26.31	11.43
2300.0	5.90	1.229	0.02	3.687	28.30	12.29
2310.0	4.90	1.310	0.01	3.929	30.16	13.10

Table XII: (cont.)

Transmission and Absorption Data of the Aqueous

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
2320.0	3.90	1.409	0.01	4.227	32.44	14.09
2330.0	3.10	1.509	0.00	4.526	34.74	15.09
2340.0	2.30	1.638	0.00	4.915	37.72	16.38
2350.0	1.70	1.770	0.00	5.309	40.75	17.70
2360.0	1.00	2.000	0.00	6.000	46.05	20.00
2370.0	0.40	2.398	0.00	7.194	55.21	23.98
2380.0	0.20	2.699	0.00	8.097	62.15	26.99
2390.0	<0.20	>2.699	0.00	>8.097	>62.15	>26.99

Table XIIIa

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
300.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
305.0	0.30	2.523	0.13	2.883	20.75	9.01
310.0	1.10	1.959	0.58	2.238	16.11	7.00
315.0	1.80	1.745	1.01	1.994	14.35	6.23
320.0	2.00	1.699	1.14	1.942	13.97	6.07
325.0	1.90	1.721	1.08	1.967	14.15	6.15
330.0	1.50	1.824	0.82	2.084	15.00	6.51
335.0	1.10	1.959	0.58	2.238	16.11	7.00
340.0	0.80	2.097	0.40	2.396	17.24	7.49
345.0	0.50	2.301	0.23	2.630	18.92	8.22
350.0	0.50	2.301	0.23	2.630	18.92	8.22
355.0	0.40	2.398	0.18	2.741	19.72	8.56
360.0	0.30	2.523	0.13	2.883	20.75	9.01
365.0	0.30	2.523	0.13	2.883	20.75	9.01
370.0	0.30	2.523	0.13	2.883	20.75	9.01
375.0	0.40	2.398	0.18	2.741	19.72	8.56
380.0	0.50	2.301	0.23	2.630	18.92	8.22
385.0	1.00	2.000	0.52	2.286	16.45	7.14
390.0	1.80	1.745	1.01	1.994	14.35	6.23

Table XIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
395.0	3.10	1.509	1.89	1.724	12.41	5.39
400.0	5.30	1.276	3.48	1.458	10.49	4.56
405.0	9.80	1.009	7.03	1.153	8.30	3.60
410.0	20.00	0.699	15.89	0.799	5.75	2.50
415.0	31.40	0.503	26.61	0.575	4.14	1.80
420.0	41.20	0.385	36.30	0.440	3.17	1.38
425.0	52.00	0.284	47.36	0.325	2.34	1.01
430.0	62.00	0.208	57.91	0.237	1.71	0.74
435.0	68.70	0.163	65.11	0.186	1.34	0.58
440.0	74.00	0.131	70.88	0.149	1.08	0.47
445.0	77.50	0.111	74.73	0.127	0.91	0.40
450.0	80.20	0.096	77.71	0.110	0.79	0.34
455.0	82.30	0.085	80.04	0.097	0.70	0.30
460.0	83.60	0.078	81.49	0.089	0.64	0.28
465.0	84.40	0.074	82.38	0.084	0.61	0.26
470.0	85.30	0.069	83.38	0.079	0.57	0.25
475.0	86.00	0.066	84.17	0.075	0.54	0.23
480.0	86.70	0.062	84.95	0.071	0.51	0.22
485.0	87.20	0.059	85.51	0.068	0.49	0.21

Table XIIIa: (c[illegible].)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
490.0	87.80	0.057	86.18	0.065	0.46	0.20
495.0	88.20	0.055	86.63	0.062	0.45	0.19
500.0	88.70	0.052	87.19	0.060	0.43	0.19
510.0	89.[illegible]	0.050	87.76	0.057	0.41	0.18
520.0	89.60	0.048	88.21	0.055	0.39	0.17
530.0	89.90	0.046	88.54	0.053	0.38	0.17
540.0	90.10	0.045	88.77	0.052	0.37	0.16
550.0	90.40	0.044	89.11	0.050	0.36	0.16
560.0	90.80	0.042	89.56	0.048	0.34	0.15
570.0	91.10	0.040	89.90	0.046	0.33	0.14
580.0	91.40	0.039	90.23	0.045	0.32	0.14
590.0	91.50	0.039	90.35	0.044	0.32	0.14
600.0	91.70	0.038	90.57	0.043	0.31	0.13
610.0	92.00	0.036	90.91	0.041	0.30	0.13
620.0	92.20	0.035	91.14	0.040	0.29	0.13
630.0	92.40	0.034	91.36	0.039	0.28	0.12
640.0	92.70	0.033	91.70	0.038	0.27	0.12
650.0	92.80	0.032	91.81	0.037	0.27	0.12
660.0	92.90	0.032	91.93	0.037	0.26	0.11

Table XIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
670.0	92.90	0.032	91.93	0.037	0.26	0.11
680.0	93.00	0.032	92.04	0.036	0.26	0.11
690.0	93.10	0.031	92.15	0.035	0.26	0.11
700.0	93.20	0.031	92.27	0.035	0.25	0.11
710.0	93.40	0.030	92.49	0.034	0.24	0.11
720.0	93.70	0.028	92.83	0.032	.23	0.10
730.0	93.80	0.028	92.95	0.032	0.23	0.10
740.0	93.80	0.028	92.95	0.032	0.23	0.10
750.0	93.80	0.028	92.95	0.032	0.23	0.10
760.0	93.90	0.027	93.06	0.031	0.22	0.10
770.0	93.90	0.027	93.06	0.031	0.22	0.10
780.0	94.00	0.027	93.17	0.031	0.22	0.10
790.0	94.00	0.027	93.17	0.031	0.22	0.10
800.0	94.10	0.026	93.29	0.030	0.22	0.09
810.0	94.10	0.026	93.29	0.030	0.22	0.09
820.0	94.10	0.026	93.29	0.030	0.22	0.09
830.0	94.00	0.027	93.17	0.031	0.22	0.10
840.0	93.90	0.027	93.06	0.031	0.22	0.10
850.0	93.80	0.028	92.95	0.032	0.23	0.10

Table VIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
860.0	93.80	0.028	92.95	0.032	0.23	0.10
870.0	93.70	0.028	92.83	0.032	0.23	0.10
880.0	93.60	0.029	92.72	0.033	0.24	0.10
890.0	93.40	0.030	92.49	0.034	0.24	0.11
900.0	93.20	0.031	92.27	0.035	0.25	0.11
910.0	93.10	0.031	92.15	0.035	0.26	0.11
920.0	92.80	0.032	91.81	0.037	0.27	0.12
930.0	92.00	0.036	90.91	0.041	0.30	0.13
940.0	91.00	0.041	89.78	0.047	0.34	0.15
950.0	89.80	0.047	88.43	0.053	0.38	0.17
960.0	87.80	0.057	86.18	0.065	0.46	0.20
970.0	85.80	0.067	83.94	0.076	0.55	0.24
980.0	85.00	0.071	83.05	0.081	0.58	0.25
990.0	85.30	0.069	83.38	0.079	0.57	0.25
1000.0	86.20	0.064	84.39	0.074	0.53	0.23
1010.0	86.90	0.061	85.17	0.070	0.50	0.22
1020.0	87.80	0.057	86.18	0.065	0.46	0.20
1030.0	88.80	0.052	87.31	0.059	0.42	0.18
1040.0	89.30	0.049	87.87	0.056	0.40	0.18

Table XIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1050.0	90.00	0.046	88.66	0.052	0.38	0.16
1060.0	90.20	0.045	88.88	0.051	0.37	0.16
1070.0	90.50	0.043	89.22	0.050	0.36	0.15
1080.0	90.50	0.043	89.22	0.050	0.36	0.15
1090.0	90.40	0.044	89.11	0.050	0.36	0.16
1100.0	90.10	0.045	88.77	0.052	0.37	0.16
1110.0	89.30	0.049	87.87	0.056	0.40	0.18
1120.0	88.00	0.056	86.41	0.063	0.46	0.20
1130.0	87.00	0.060	85.29	0.069	0.50	0.22
1140.0	85.00	0.071	83.05	0.081	0.58	0.25
1150.0	82.70	0.082	80.49	0.094	0.68	0.29
1160.0	79.00	0.102	76.38	0.117	0.84	0.37
1170.0	72.00	0.143	68.70	0.163	1.17	0.51
1180.0	69.80	0.156	66.31	0.178	1.28	0.56
1190.0	69.10	0.161	65.55	0.183	1.32	0.57
1200.0	69.00	0.161	65.44	0.184	1.33	0.58
1210.0	69.30	0.159	65.76	0.182	1.31	0.57
1220.0	69.90	0.156	66.41	0.178	1.28	0.56
1230.0	70.80	0.150	67.39	0.171	1.23	0.54

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1240.0	71.70	0.144	68.37	0.165	1.19	0.52
1250.0	72.90	0.137	69.68	0.157	1.13	0.49
1260.0	73.90	0.131	70.77	0.150	1.08	0.47
1270.0	74.00	0.131	70.88	0.149	1.08	0.47
1280.0	73.80	0.132	70.67	0.151	1.09	0.47
1290.0	72.50	0.140	69.24	0.160	1.15	0.50
1300.0	70.90	0.149	67.50	0.171	1.23	0.53
1310.0	69.00	0.161	65.44	0.184	1.33	0.58
1320.0	66.80	0.175	63.06	0.200	1.44	0.63
1330.0	63.90	0.194	59.94	0.222	1.60	0.69
1340.0	59.00	0.229	54.72	0.262	1.88	0.82
1350.0	49.40	0.306	44.67	0.350	2.52	1.09
1360.0	40.00	0.398	35.09	0.455	3.27	1.42
1370.0	31.00	0.509	26.22	0.581	4.18	1.82
1380.0	21.90	0.660	17.63	0.754	5.42	2.36
1390.0	12.90	0.889	9.63	1.016	7.31	3.18
1400.0	3.00	1.523	1.82	1.740	12.52	5.44
1410.0	0.80	2.097	0.40	2.396	17.24	7.49
1420.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

Table XIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1430.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1440.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1450.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1460.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1470.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1480.0	0.20	2.699	0.08	3.085	22.20	9.64
1490.0	0.30	2.523	0.13	2.883	20.75	9.01
1500.0	0.50	2.301	0.23	2.630	18.92	8.22
1510.0	0.80	2.097	0.40	2.396	17.24	7.49
1520.0	1.30	1.886	0.70	2.155	15.51	6.74
1530.0	2.10	1.678	1.21	1.917	13.80	5.99
1540.0	3.30	1.481	2.03	1.693	12.18	5.29
1550.0	5.00	1.301	3.26	1.487	10.70	4.65
1560.0	7.00	1.155	4.79	1.320	9.50	4.12
1570.0	9.00	1.046	6.38	1.195	8.60	3.73
1580.0	10.80	0.967	7.86	1.105	7.95	3.45
1590.0	13.00	0.886	9.71	1.013	7.29	3.16
1600.0	15.10	0.821	11.53	0.938	6.75	2.93
1610.0	17.00	0.770	13.20	0.879	6.33	2.75

Table XIIIa: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1620.0	18.80	0.726	14.81	0.830	5.97	2.59
1630.0	20.20	0.695	16.07	0.794	5.71	2.48
1640.0	21.70	0.664	17.44	0.758	5.46	2.37
1650.0	22.70	0.644	18.37	0.736	5.30	2.30
1660.0	22.90	0.640	18.55	0.732	5.26	2.29
1670.0	22.80	0.642	18.46	0.734	5.28	2.29
1680.0	22.30	0.652	18.00	0.745	5.36	2.33
1690.0	21.70	0.664	17.44	0.758	5.46	2.37
1700.0	20.80	0.682	16.62	0.779	5.61	2.44
1710.0	19.80	0.703	15.71	0.804	5.78	2.51
1720.0	18.50	0.733	14.54	0.838	6.03	2.62
1730.0	17.20	0.764	13.38	0.874	6.29	2.73
1740.0	15.40	0.812	11.79	0.929	6.68	2.90
1750.0	14.10	0.851	10.66	0.972	7.00	3.04
1760.0	12.90	0.889	9.63	1.016	7.31	3.18
1770.0	11.80	0.928	8.70	1.061	7.63	3.31
1780.0	10.90	0.963	7.94	1.100	7.92	3.44
1790.0	10.60	0.975	7.69	1.114	8.02	3.48
1800.0	10.40	0.983	7.53	1.123	8.08	3.51

Table XIIIe: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1810.0	10.30	0.987	7.44	1.128	8.12	3.53
1820.0	10.30	0.987	7.44	1.128	8.12	2.53
1830.0	10.10	0.996	7.28	1.138	8.19	3.56
1840.0	9.80	1.009	7.03	1.153	8.30	3.60
1850.0	8.70	1.060	6.14	1.212	8.72	3.79
1860.0	5.10	1.292	3.33	1.477	10.63	4.62
1870.0	1.70	1.770	0.95	2.022	14.55	6.32
1880.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

Table XIII

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
300.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
305.0	0.30	2.523	0.13	2.883	20.75	9.01
310.0	1.10	1.959	0.58	2.238	16.11	7.00
315.0	1.80	1.745	1.01	1.994	14.35	6.23
320.0	2.00	1.699	1.14	1.942	13.97	6.07
325.0	1.90	1.721	1.08	1.967	14.15	6.15
330.0	1.50	1.824	0.82	2.084	15.00	6.51
335.0	1.10	1.959	0.58	2.238	16.11	7.00
340.0	0.80	2.097	0.40	2.396	17.24	7.49
345.0	0.50	2.301	0.23	2.630	18.92	8.22
350.0	0.50	2.301	0.23	2.630	18.92	8.22
355.0	0.40	2.398	0.18	2.741	19.72	8.56
360.0	0.30	2.523	0.13	2.883	20.75	9.01
365.0	0.30	2.523	0.13	2.883	20.75	9.01
370.0	0.30	2.523	0.13	2.883	20.75	9.01
375.0	0.40	2.398	0.18	2.741	19.72	8.56
380.0	0.50	2.301	0.23	2.630	18.92	8.22
385.0	1.00	2.000	0.52	2.286	16.45	7.14
390.0	1.80	1.745	1.01	1.994	14.35	6.23

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
395.0	3.10	1.509	1.89	1.724	12.41	5.39
400.0	5.50	1.260	3.63	1.440	10.36	4.50
405.0	9.80	1.009	7.03	1.153	8.30	3.60
410.0	19.80	0.703	15.71	0.804	5.78	2.51
415.0	27.00	0.569	22.39	0.650	4.68	2.03
420.0	35.10	0.455	30.22	0.520	3.74	1.62
425.0	45.00	0.347	40.15	0.396	2.85	1.24
430.0	50.10	0.300	45.39	0.343	2.47	1.07
435.0	53.90	0.268	49.35	0.307	2.21	0.96
440.0	56.90	0.245	52.50	0.280	2.01	0.87
445.0	59.40	0.226	55.14	0.259	1.86	0.81
450.0	61.00	0.215	56.84	[illegible]	1.77	0.77
455.0	62.30	0.206	58.23	0.235	1.69	0.73
460.0	63.20	0.199	59.19	0.228	1.64	0.71
465.0	63.90	0.194	59.94	0.222	1.60	0.69
470.0	64.70	0.189	60.80	0.216	1.56	0.68
475.0	65.10	0.136	61.23	0.213	1.53	0.67
480.0	65.60	0.183	61.77	0.209	1.51	0.65
485.0	66.00	0.180	62.20	0.206	1.48	0.64

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
490.0	66.40	0.178	62.63	0.203	1.46	0.64
495.0	66.80	0.175	63.06	0.200	1.44	0.63
500.0	67.00	0.174	63.27	0.199	1.43	0.62
510.0	67.80	0.169	64.14	0.193	1.39	0.60
520.0	68.30	0.166	64.68	0.189	1.36	0.59
530.0	68.80	0.162	65.22	0.186	1.34	0.58
540.0	69.10	0.161	65.55	0.183	1.32	0.57
550.0	69.50	0.158	65.98	0.181	1.30	0.56
560.0	69.90	0.156	66.41	0.178	1.28	0.56
570.0	70.00	0.155	66.52	0.177	1.27	0.55
580.0	70.00	0.155	66.52	0.177	1.27	0.55
590.0	70.10	0.154	66.63	0.176	1.27	0.55
600.0	70.20	0.154	66.74	0.176	1.26	0.55
610.0	70.40	0.152	66.96	0.174	1.25	0.54
620.0	70.60	0.151	67.17	0.173	1.24	0.54
630.0	70.70	0.151	67.28	0.172	1.24	0.54
640.0	70.80	0.150	67.39	0.171	1.23	0.54
650.0	70.80	0.150	67.39	0.171	1.23	0.54
660.0	70.90	0.149	67.50	0.171	1.23	0.53

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
670.0	70.90	0.149	67.50	0.171	1.23	0.53
680.0	70.90	0.149	67.50	0.171	1.23	0.53
690.0	71.00	0.149	67.61	0.170	1.22	0.53
700.0	71.10	0.148	67.72	0.169	1.22	0.53
710.0	71.20	0.148	67.83	0.169	1.21	0.53
720.0	71.20	0.148	67.83	0.169	1.21	0.53
730.0	71.50	0.146	68.15	0.167	1.20	0.52
740.0	71.60	0.145	68.26	0.166	1.19	0.52
750.0	71.70	0.144	68.37	0.165	1.19	0.52
760.0	71.80	0.144	68.48	0.164	1.18	0.51
770.0	71.80	0.144	68.48	0.164	1.18	0.51
780.0	71.80	0.144	68.48	0.164	1.18	0.51
790.0	71.90	0.143	68.59	0.164	1.18	0.51
800.0	72.00	0.143	68.70	0.163	1.17	0.51
810.0	72.00	0.143	68.70	0.163	1.17	0.51
820.0	72.00	0.143	68.70	0.163	1.17	0.51
830.0	72.00	0.143	68.70	0.163	1.17	0.51
840.0	72.00	0.143	68.70	0.163	1.17	0.51
850.0	72.00	0.143	68.70	0.163	1.17	0.51

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
860.0	72.00	0.143	68.70	0.163	1.17	0.51
870.0	72.00	0.143	68.70	0.163	1.17	0.51
880.0	72.00	0.143	68.70	0.163	1.17	0.51
890.0	71.90	0.143	68.59	0.164	1.18	0.51
900.0	71.80	0.144	68.48	0.164	1.18	0.51
910.0	71.40	0.146	68.05	0.167	1.20	0.52
920.0	70.80	0.150	67.39	0.171	1.23	0.54
930.0	69.90	0.156	66.41	0.178	1.28	0.56
940.0	68.80	0.162	65.22	0.186	1.34	0.58
950.0	67.10	0.173	63.38	0.198	1.42	0.62
960.0	65.50	0.184	61.66	0.210	1.51	0.66
970.0	64.10	0.193	60.15	0.221	1.59	0.69
980.0	63.00	0.201	58.98	0.229	1.65	0.72
990.0	63.60	0.197	59.62	0.225	1.62	0.70
1000.0	64.80	0.188	60.91	0.215	1.55	0.67
1010.0	65.30	0.185	61.44	0.212	1.52	0.66
1020.0	65.90	0.181	62.09	0.207	1.49	0.65
1030.0	66.20	0.179	62.41	0.205	1.47	0.64
1040.0	66.60	0.177	62.84	0.202	1.45	0.63

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1050.0	66.80	0.175	63.06	0.200	1.44	0.63
1060.0	66.90	0.175	63.17	0.200	1.44	0.62
1070.0	70.00	0.155	66.52	0.177	1.27	0.55
1080.0	70.00	0.155	66.52	0.177	1.27	0.55
1090.0	66.80	0.175	63.06	0.200	1.44	0.63
1100.0	66.00	0.180	62.20	0.206	1.48	0.64
1110.0	64.80	0.188	60.91	0.215	1.55	0.67
1120.0	63.70	0.196	59.73	0.224	1.61	0.70
1130.0	62.00	0.208	57.91	0.237	1.71	0.74
1140.0	60.10	0.221	55.88	0.253	1.82	0.79
1150.0	58.00	0.237	53.66	0.270	1.95	0.84
1160.0	54.70	0.262	50.18	0.299	2.15	0.94
1170.0	51.50	0.288	46.84	0.329	2.37	1.03
1180.0	49.30	0.307	44.56	0.351	2.53	1.10
1190.0	48.30	0.316	43.53	0.361	2.60	1.13
1200.0	48.10	0.318	43.32	0.363	2.61	1.14
1210.0	48.30	0.316	43.53	0.361	2.60	1.13
1220.0	48.80	0.312	44.05	0.356	2.56	1.11
1230.0	49.30	0.307	44.56	0.351	2.53	1.10

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1240.0	50.00	0.301	45.29	0.344	2.48	1.08
1250.0	51.00	0.292	46.32	0.334	2.40	1.04
1260.0	51.80	0.286	47.15	0.326	2.35	1.02
1270.0	51.80	0.286	47.15	0.326	2.35	1.02
1280.0	51.40	0.289	46.74	0.330	2.38	1.03
1290.0	50.40	0.298	45.70	0.340	2.45	1.06
1300.0	49.10	0.309	44.36	0.353	2.54	1.10
1310.0	47.40	0.324	42.61	0.371	2.67	1.16
1320.0	45.20	0.345	40.35	0.394	2.84	1.23
1330.0	43.60	0.361	38.72	0.412	2.96	1.29
1340.0	40.00	0.398	35.09	0.455	3.27	1.42
1350.0	37.00	0.432	32.10	0.493	3.55	1.54
1360.0	33.90	0.470	29.05	0.537	3.86	1.68
1370.0	29.00	0.538	24.30	0.614	4.42	1.92
1380.0	21.90	0.660	17.63	0.754	5.42	2.36
1390.0	12.90	0.889	9.63	1.016	7.31	3.18
1400.0	3.00	1.523	1.82	1.740	12.52	5.44
1410.0	0.80	2.097	0.40	2.396	17.24	7.49
1420.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1430.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
1440.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
1450.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
1460.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
1470.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
1480.0	0.20	2.699	0.08	3.085	22.20	9.64
1490.0	0.30	2.523	0.13	2.883	20.75	9.01
1500.0	0.50	2.301	0.23	2.630	18.92	8.22
1510.0	0.80	2.097	0.40	2.396	17.24	7.49
1520.0	1.30	1.886	0.70	2.155	15.51	6.74
1530.0	2.10	1.678	1.21	1.917	13.80	5.99
1540.0	3.30	1.481	2.03	1.693	12.18	5.29
1550.0	5.00	1.301	3.26	1.487	10.70	4.65
1560.0	6.20	1.208	4.17	1.380	9.93	4.31
1570.0	7.80	1.108	5.42	1.266	9.11	3.96
1580.0	9.70	1.013	6.95	1.158	8.33	3.62
1590.0	11.10	0.955	8.11	1.091	7.85	3.41
1600.0	12.70	0.896	9.46	1.024	7.37	3.20
1610.0	14.00	0.854	10.57	0.976	7.02	3.05

Table XIIIB: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1620.0	15.30	0.815	11.70	0.932	6.70	2.91
1630.0	16.80	0.775	13.02	0.885	6.37	2.77
1640.0	17.80	0.750	13.91	0.857	6.16	2.68
1650.0	18.60	0.730	14.63	0.835	6.01	2.61
1660.0	19.00	0.721	14.99	0.824	5.93	2.58
1670.0	18.90	0.724	14.90	0.827	5.95	2.58
1680.0	18.50	0.733	14.54	0.838	6.03	2.62
1690.0	18.00	0.745	14.09	0.851	6.12	2.66
1700.0	17.20	0.764	13.38	0.874	6.29	2.73
1710.0	16.50	0.783	12.76	0.894	6.44	2.79
1720.0	15.80	0.801	12.14	0.916	6.59	2.86
1730.0	14.80	0.830	11.26	0.948	6.82	2.96
1740.0	13.70	0.863	10.31	0.987	7.10	3.08
1750.0	12.70	0.896	9.46	1.024	7.37	3.20
1760.0	11.70	0.932	8.61	1.065	7.66	3.33
1770.0	10.70	0.971	7.78	1.109	7.98	3.47
1780.0	10.00	1.000	7.20	1.143	8.22	3.57
1790.0	9.80	1.009	7.03	1.153	8.30	3.60
1800.0	9.60	1.018	6.87	1.163	8.37	3.63

Table XIIIb: (cont.)

Direct Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1810.0	9.50	1.022	6.79	1.168	8.41	3.65
1820.0	9.40	1.027	6.71	1.174	8.44	3.67
1830.0	9.20	1.036	6.54	1.184	8.52	3.70
1840.0	8.70	1.060	6.14	1.212	8.72	3.79
1850.0	7.60	1.119	5.26	1.279	9.20	4.00
1860.0	5.10	1.292	3.33	1.477	10.63	4.62
1870.0	1.70	1.770	0.95	2.022	14.55	6.32
1880.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

Table XIV

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
300.0	< 0.20	> 2.699	< 0.08	> 3.085	> 22.20	> 9.64
305.0	0.90	2.046	0.46	2.338	16.82	7.31
310.0	2.80	1.553	1.68	1.775	12.77	5.55
315.0	4.50	1.347	2.89	1.539	11.08	4.81
320.0	4.90	1.310	3.18	1.497	10.77	4.68
325.0	4.80	1.319	3.11	1.507	10.84	4.71
330.0	4.00	1.398	2.53	1.598	11.50	4.99
335.0	3.20	1.495	1.96	1.708	12.29	5.34
340.0	2.40	1.620	1.41	1.851	13.32	5.78
345.0	1.80	1.745	1.01	1.994	14.35	6.23
350.0	1.20	1.921	0.64	2.195	15.80	6.86
355.0	1.00	2.000	0.52	2.286	16.45	7.14
360.0	1.00	2.000	0.52	2.286	16.45	7.14
365.0	1.00	2.000	0.52	2.286	16.45	7.14
370.0	1.00	2.000	0.52	2.286	16.45	7.14
375.0	1.00	2.000	0.52	2.286	16.45	7.14
380.0	1.20	1.921	0.64	2.195	15.80	6.86
385.0	1.70	1.770	0.95	2.022	14.55	6.32
390.0	2.20	1.658	1.28	1.894	13.63	5.92

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
395.0	3.10	1.509	1.89	1.724	12.41	5.39
400.0	5.30	1.276	3.48	1.458	10.49	4.56
405.0	9.60	1.009	7.03	1.153	8.30	3.60
410.0	23.50	0.629	19.11	0.719	5.17	2.25
415.0	37.80	0.423	32.90	0.483	3.47	1.51
420.0	51.80	0.286	47.15	0.326	2.35	1.02
425.0	62.10	0.207	58.01	0.236	1.70	0.74
430.0	70.00	0.155	66.52	0.177	1.27	0.55
435.0	76.90	0.114	74.07	0.130	0.94	0.41
440.0	82.20	0.085	79.93	0.097	0.70	0.30
445.0	85.40	0.069	83.50	0.078	0.56	0.24
450.0	87.30	0.059	85.62	0.067	0.49	0.21
455.0	89.00	0.051	87.53	0.058	0.42	0.18
460.0	90.00	0.046	88.66	0.052	0.38	0.16
465.0	90.90	0.041	89.67	0.047	0.34	0.15
470.0	91.80	0.037	90.68	0.042	0.31	0.13
475.0	92.40	0.034	91.36	0.039	0.28	0.12
480.0	93.00	0.032	92.04	0.036	0.26	0.11
485.0	93.50	0.029	92.61	0.033	0.24	0.10

Table XIV; (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
490.0	93.90	0.027	93.06	0.031	0.22	0.10
495.0	94.30	0.025	93.51	0.029	0.21	0.09
500.0	94.60	0.024	93.85	0.028	0.20	0.09
510.0	95.00	0.022	94.31	0.025	0.18	0.08
520.0	95.20	0.021	94.53	0.024	0.18	0.08
530.0	95.60	0.020	94.99	0.022	0.16	0.07
540.0	95.90	0.018	95.33	0.021	0.15	0.06
550.0	96.10	0.017	95.56	0.020	0.14	0.06
560.0	96.20	0.017	95.67	0.019	0.14	0.06
570.0	96.30	0.016	95.78	0.019	0.13	0.06
580.0	96.60	0.015	96.12	0.017	0.12	0.05
590.0	96.70	0.015	96.24	0.017	0.12	0.05
600.0	96.80	0.014	96.35	0.016	0.12	0.05
610.0	96.80	0.014	96.35	0.016	0.12	0.05
620.0	96.90	0.014	96.47	0.016	0.11	0.05
630.0	96.90	0.014	96.47	0.016	0.11	0.05
640.0	96.90	0.014	96.47	0.016	0.11	0.05
650.0	97.00	0.013	96.58	0.015	0.11	0.05
660.0	97.10	0.013	96.69	0.015	0.11	0.05

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
670.0	97.10	0.013	96.69	0.015	0.11	0.05
680.0	97.20	0.012	96.81	0.014	0.10	0.04
690.0	97.20	0.012	96.81	0.014	0.10	0.04
700.0	97.30	0.012	96.92	0.014	0.10	0.04
710.0	97.50	0.011	97.15	0.013	0.09	0.04
720.0	97.60	0.011	97.26	0.012	0.09	0.04
730.0	97.70	0.010	97.38	0.012	0.08	0.04
740.0	97.80	0.010	97.49	0.011	0.08	0.03
750.0	97.80	0.010	97.49	0.011	0.08	0.03
760.0	97.90	0.009	97.60	0.011	0.08	0.03
770.0	97.90	0.009	97.60	0.011	0.08	0.03
780.0	97.90	0.009	97.60	0.011	0.08	0.03
790.0	98.00	0.009	97.72	0.010	0.07	0.03
800.0	98.00	0.009	97.72	0.010	0.07	0.03
810.0	98.00	0.009	97.72	0.010	0.07	0.03
820.0	98.00	0.009	97.72	0.010	0.07	0.03
830.0	98.00	0.009	97.72	0.010	0.07	0.03
840.0	98.00	0.009	97.72	0.010	0.07	0.03
850.0	98.00	0.009	97.72	0.010	0.07	0.03

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
860.0	98.00	0.009	97.72	0.010	0.07	0.03
870.0	97.90	0.009	97.60	0.011	0.08	0.03
880.0	97.90	0.009	97.60	0.011	0.08	0.03
890.0	97.80	0.010	97.49	0.011	0.08	0.03
900.0	97.60	0.011	97.26	0.012	0.09	0.04
910.0	97.30	0.012	96.92	0.014	0.10	0.04
920.0	96.80	0.014	96.35	0.016	0.12	0.05
930.0	95.90	0.018	95.33	0.021	0.15	0.06
940.0	94.80	0.023	94.08	0.027	0.19	0.08
950.0	93.20	0.031	92.27	0.035	0.25	0.11
960.0	91.50	0.039	90.35	0.044	0.32	0.14
970.0	89.90	0.046	88.54	0.053	0.38	0.17
980.0	89.00	0.051	87.53	0.058	0.42	0.18
990.0	88.90	0.051	87.42	0.058	0.42	0.18
1000.0	90.10	0.045	88.77	0.052	0.37	0.16
1010.0	90.90	0.041	89.67	0.047	0.34	0.15
1020.0	91.60	0.038	90.46	0.044	0.31	0.14
1030.0	92.20	0.035	91.14	0.040	0.29	0.13
1040.0	92.80	0.032	91.81	0.037	0.27	0.12

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1050.0	93.20	0.031	92.27	0.035	0.25	0.11
1060.0	93.40	0.030	92.49	0.034	0.24	0.11
1070.0	93.50	0.029	92.61	0.033	0.24	0.10
1080.0	93.40	0.030	92.49	0.034	0.24	0.11
1090.0	93.20	0.031	92.27	0.035	0.25	0.11
1100.0	93.00	0.032	92.04	0.036	0.26	0.11
1110.0	92.20	0.035	91.14	0.040	0.29	0.13
1120.0	91.20	0.040	90.01	0.046	0.33	0.14
1130.0	90.00	0.046	88.66	0.052	0.38	0.16
1140.0	88.70	0.052	87.19	0.060	0.43	0.19
1150.0	86.20	0.064	84.39	0.074	0.53	0.23
1160.0	83.30	0.079	81.15	0.091	0.65	0.28
1170.0	79.60	0.099	77.05	0.113	0.81	0.35
1180.0	74.00	0.131	70.88	0.149	1.08	0.47
1190.0	71.80	0.144	68.48	0.164	1.18	0.51
1200.0	71.60	0.145	68.26	0.166	1.19	0.52
1210.0	71.90	0.143	68.59	0.164	1.18	0.51
1220.0	72.80	0.138	69.57	0.158	1.13	0.49
1230.0	73.50	0.134	70.34	0.153	1.10	0.48

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1240.0	74.80	0.126	71.76	0.144	1.04	0.45
1250.0	75.80	0.120	72.86	0.138	0.99	0.43
1260.0	76.40	0.117	73.52	0.134	0.96	0.42
1270.0	76.70	0.115	73.85	0.132	0.95	0.41
1280.0	76.20	0.118	73.30	0.135	0.97	0.42
1290.0	75.00	0.125	71.98	0.143	1.03	0.45
1300.0	73.30	0.135	70.12	0.154	1.11	0.48
1310.0	71.50	0.146	68.15	0.167	1.20	0.52
1320.0	69.10	0.161	65.55	0.183	1.32	0.57
1330.0	66.80	0.175	63.06	0.200	1.44	0.63
1340.0	63.10	0.200	59.08	0.229	1.64	0.71
1350.0	53.20	0.274	48.61	0.313	2.25	0.98
1360.0	43.10	0.366	38.22	0.418	3.01	1.31
1370.0	33.10	0.480	28.26	0.549	3.95	1.71
1380.0	23.00	0.638	18.64	0.729	5.25	2.28
1390.0	12.90	0.889	9.63	1.016	7.31	3.18
1400.0	3.00	1.523	1.82	1.740	12.52	5.44
1410.0	0.80	2.097	0.40	2.396	17.24	7.49
1420.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1430.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1440.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1450.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1460.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1470.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64
1480.0	0.20	2.699	0.08	3.085	22.20	9.64
1490.0	0.30	2.523	0.13	2.883	20.75	9.01
1500.0	0.50	2.301	0.23	2.630	18.92	8.22
1510.0	0.80	2.097	0.40	2.396	17.24	7.49
1520.0	1.30	1.886	0.70	2.155	15.51	6.74
1530.0	2.10	1.673	1.21	1.917	13.80	5.99
1540.0	3.30	1.481	2.03	1.693	12.18	5.29
1550.0	5.00	1.301	3.26	1.487	10.70	4.65
1560.0	7.00	1.155	4.79	1.320	9.50	4.12
1570.0	9.20	1.036	6.54	1.184	8.52	3.70
1580.0	11.80	0.928	8.70	1.061	7.63	3.31
1590.0	14.20	0.848	10.74	0.969	6.97	3.03
1600.0	16.60	0.780	12.84	0.891	6.41	2.79
1610.0	18.80	0.726	14.81	0.830	5.97	2.59

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1620.0	20.30	0.693	16.16	0.791	5.69	2.47
1630.0	22.10	0.656	17.81	0.749	5.39	2.34
1640.0	23.50	0.629	19.11	0.719	5.17	2.25
1650.0	24.60	0.609	20.13	0.696	5.01	2.18
1660.0	24.80	0.606	20.32	0.692	4.98	2.16
1670.0	24.70	0.607	20.23	0.694	4.99	2.17
1680.0	24.10	0.618	19.67	0.706	5.08	2.21
1690.0	23.50	0.629	19.11	0.719	5.17	2.25
1700.0	22.40	0.650	18.09	0.743	5.34	2.32
1710.0	21.00	0.678	16.80	0.775	5.57	2.42
1720.0	19.80	0.703	15.71	0.804	5.78	2.51
1730.0	17.00	0.770	13.20	0.879	6.33	2.75
1740.0	16.30	0.788	12.58	0.900	6.48	2.81
1750.0	14.80	0.830	11.26	0.948	6.82	2.96
1760.0	13.50	0.870	10.14	0.994	7.15	3.11
1770.0	12.20	0.914	9.03	1.044	7.51	3.26
1780.0	11.50	0.939	8.44	1.073	7.72	3.35
1790.0	11.10	0.955	8.11	1.091	7.85	3.41
1800.0	11.00	0.959	8.03	1.096	7.88	3.42

Table XIV: (cont.)

Total Transmission and Absorption Data of the Lens

LAMBDA	% TRAN MONKEY	ABSORBANCE MONKEY	% TRAN HUMAN	ABSORBANCE HUMAN	ALPHA	ABSORPTIVITY
1810.0	11.00	0.959	8.03	1.096	7.88	3.42
1820.0	10.80	0.967	7.86	1.105	7.95	3.45
1830.0	10.60	0.975	7.69	1.114	8.02	3.48
1840.0	10.00	1.000	7.20	1.143	8.22	3.57
1850.0	8.70	1.060	6.14	1.212	8.72	3.79
1860.0	5.10	1.292	3.33	1.477	10.63	4.62
1870.0	1.70	1.770	0.95	2.022	14.55	6.32
1880.0	<0.20	>2.699	<0.08	>3.085	>22.20	>9.64

APPENDIX V: 1967 DATA

Tables XV through XIX contain the data obtained in our previous measurements of the transmission of the human ocular media (3), and the conversion of this data into absorption coefficients and absorbance, by means of the computer programs. Tables XX through XXIV are a similar presentation of our previous data on monkey eyes. The same thicknesses of the ocular media of humans and monkeys was used in the previous work, with one exception. The aqueous humor of the monkey was measured at a thickness of 0.5 mm but the data as reported was converted to the transmission corresponding to a thickness of 2.6 mm. This accounts for the lower and higher values, respectively, of columns 2 and 3 of Table XXII when compared with the same columns of Table XII, where a thickness of 1 mm was used.

Another difference in the computation of the 1967 data was that no corrections were made for reflection losses between the specimens and the inner cell windows, the rational being that such losses were generally less than the precision of the measurements. This assumption was valid as only quartz windows were used, so that the difference in index of refraction between the window and specimen was small. In the present measurements, it was the use of the Irtran windows, with their higher indices of refraction, that made the inner cell reflection corrections necessary.

With the data now all on a common basis, it is possible to intercompare the recent measurements with the earlier work. Of interest is a comparison of the projection of recent measurements into that expected in the human ocular media, with the actual measured values obtained earlier on the human eye. Such a comparison looks reasonably good except in those spectral regions indicated below.

<u>Cornea</u>: From 320 to 400 nm the new data gives a total transmission less than previous, due to a lesser slope in this cut-off region.

<u>Aqueous</u>: The new data, as projected to the human eye, gives a better transmission of the aqueous from 300 to 500 nm, resulting from a sharper

cut-off at about 300 nm. Also, the small ultraviolet window from 200 to 265 nm translates into a transmission of 1.5% in the human at 230 nm, while the older data gave a maximum of half of this value.

Lens: The short wave cut-off of transmission in the 400 to 480 nm region is more abrupt in the newer data with the result that the total transmissions are less to about 500 nm, and slightly greater at longer wavelengths. The same is the case for the direct transmission data, except that the cross-over point is about 440 nm, and the transmissions are greater in the visible for the new data.

Table XV

Direct Transmission and Absorption Data of the Cornea (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
280.0	<0.20	>2.699	>163.58	>44.98
300.0	2.00	1.699	65.20	28.32
320.0	27.00	0.569	21.32	9.48
340.0	35.00	0.456	17.50	7.60
360.0	43.00	0.367	14.07	6.11
380.0	48.00	0.319	12.23	5.31
400.0	52.00	0.284	10.90	4.73
420.0	55.00	0.260	9.96	4.33
440.0	58.50	0.233	8.94	3.88
460.0	61.50	0.211	3.10	3.52
480.0	63.50	0.197	7.57	3.29
500.0	64.50	0.190	7.31	3.17
550.0	67.50	0.171	6.55	2.84
600.0	70.50	0.152	5.83	2.53
650.0	73.00	0.137	5.25	2.28
700.0	76.00	0.119	4.57	1.99
750.0	78.00	0.108	4.14	1.80
800.0	79.50	0.100	3.82	1.66
850.0	81.00	0.092	3.51	1.53

Table XV: (cont.)

Direct Transmission and Absorption Data of the Cornea (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
900.0	82.00	0.086	3.31	1.44
950.0	81.50	0.089	3.41	1.48
980.0	81.00	0.092	3.51	1.53
1000.0	82.00	0.086	3.31	1.44
1100.0	85.50	0.068	2.61	1.13
1200.0	80.50	0.094	3.62	1.57
1300.0	82.50	0.084	3.21	1.39
1400.0	40.00	0.398	15.27	6.63
1445.0	19.00	0.721	27.68	12.02
1500.0	27.50	0.561	21.52	9.34
1600.0	58.50	0.233	8.94	3.88
1700.0	64.00	0.194	7.44	3.23
1800.0	56.00	0.252	9.66	4.20
1900.0	3.00	1.523	58.44	25.38
1950.0	<0.20	>2.699	>103.58	>44.98
2000.0	1.00	2.000	76.75	33.33
2100.0	17.00	0.770	29.53	12.83
2200.0	26.50	0.577	22.13	9.61
2300.0	18.00	0.745	28.56	12.41

Table XV: (cont.)

Direct Transmission and Absorption Data of the Cornea (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
2400.0	5.50	1.260	48.34	20.99
2500.0	<0.20	>2.699	>103.58	>44.98

Table XVI: (cont.)

Total Transmission and Absorption Data of the Cornea (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
900.0	95.50	0.020	0.77	0.33
950.0	95.00	0.022	0.85	0.37
980.0	93.50	0.029	1.12	0.49
1000.0	94.00	0.027	1.03	0.45
1100.0	94.50	0.025	0.94	0.41
1200.0	91.50	0.039	1.48	0.64
1300.0	90.50	0.043	1.66	0.72
1400.0	59.50	0.225	8.65	3.76
1445.0	25.00	0.602	23.10	10.03
1500.0	33.00	0.481	18.48	8.02
1600.0	68.00	0.167	6.43	2.79
1700.0	71.00	0.149	5.71	2.48
1800.0	62.00	0.208	7.97	3.46
1900.0	5.00	1.301	49.93	21.68
1950.0	0.50	2.301	88.31	38.35
2000.0	3.00	1.523	58.44	25.38
2100.0	22.00	0.658	25.24	10.96
2200.0	31.00	0.509	19.52	8.48
2300.0	21.00	0.678	26.01	11.30

Table XVI: (cont.)

Total Transmission and Absorption Data of the Cornea (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
2400.0	8.00	1.097	42.10	18.28
2500.0	0.50	2.301	88.31	38.35

Table XVII

Transmission and Absorption Data of the Aqueous (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
280.0	<0.20	>2.699	>20.72	>9.00
300.0	17.50	0.757	5.81	2.52
320.0	78.00	0.108	0.83	0.36
340.0	83.00	0.081	0.62	0.27
360.0	86.00	0.065	0.50	0.22
380.0	88.50	0.053	0.41	0.18
400.0	90.00	0.046	0.35	0.15
420.0	91.00	0.041	0.31	0.14
440.0	92.00	0.036	0.28	0.12
460.0	93.50	0.029	0.22	0.10
480.0	93.50	0.029	0.22	0.10
500.0	94.00	0.027	0.21	0.09
550.0	96.00	0.018	0.14	0.06
600.0	96.50	0.015	0.12	0.05
650.0	97.50	0.011	0.08	0.04
700.0	97.50	0.011	0.09	0.04
750.0	97.50	0.011	0.08	0.04
800.0	97.00	0.013	0.10	0.04
850.0	96.50	0.015	0.12	0.05

Table XVII: (cont.)

Transmission and Absorption Data of the Aqueous (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
900.0	94.50	0.025	0.19	0.08
950.0	90.00	0.046	0.35	0.15
980.0	84.50	0.073	0.56	0.24
1000.0	87.00	0.060	0.46	0.20
1100.0	88.00	0.056	0.43	0.19
1200.0	65.50	0.184	1.41	0.61
1300.0	67.00	0.174	1.33	0.58
1400.0	0.50	2.301	17.66	7.67
1445.0	<0.20	>2.699	>20.72	>9.00
1500.0	<0.20	>2.699	>20.72	>9.00
1600.0	9.00	1.046	8.03	3.49
1700.0	15.00	0.824	6.32	2.75
1800.0	6.00	1.222	9.38	4.07
1900.0	<0.20	>2.699	>20.72	>9.00
1950.0	<0.20	>2.699	>20.72	>9.00
2000.0	<0.20	>2.699	>20.72	>9.00
2100.0	<0.20	>2.699	>20.72	>9.00
2200.0	0.20	2.699	20.72	9.00
2300.0	<0.20	>2.699	>20.72	>9.00

Table XVIII

Direct Transmission and Absorption Data of the Lens (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
300.0	<0.20	>2.699	>19.42	>8.43
320.0	6.50	1.187	8.54	3.71
340.0	2.00	1.699	12.23	5.31
360.0	0.50	2.301	16.56	7.19
380.0	1.00	2.000	14.39	6.25
400.0	12.00	0.921	6.63	2.88
420.0	56.00	0.252	1.81	0.79
440.0	71.00	0.149	1.07	0.46
460.0	74.00	0.131	0.94	0.41
480.0	76.00	0.119	0.86	0.37
500.0	78.50	0.105	0.76	0.33
550.0	82.00	0.086	0.62	0.27
600.0	85.00	0.071	0.51	0.22
650.0	87.00	0.060	0.44	0.19
700.0	88.00	0.056	0.40	0.17
750.0	88.00	0.056	0.40	0.17
800.0	88.50	0.053	0.38	0.17
850.0	89.50	0.048	0.35	0.15
900.0	90.00	0.046	0.33	0.14

Table XVIII: (cont.)

Direct Transmission and Absorption Data of the Lens (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
950.0	84.50	0.073	0.53	0.23
980.0	79.00	0.102	0.74	0.32
1000.0	80.50	0.094	0.68	0.29
1100.0	86.00	0.056	0.47	0.20
1200.0	64.50	0.190	1.37	0.60
1300.0	67.00	0.174	1.25	0.54
1400.0	1.50	1.824	13.12	5.70
1445.0	<0.20	>2.699	>19.42	>8.43
1500.0	0.20	2.699	19.42	8.43
1600.0	9.50	1.022	7.36	3.19
1700.0	11.50	0.939	6.76	2.94
1800.0	5.50	1.260	9.06	3.94
1900.0	<0.20	>2.699	>19.42	>8.43

Table XIX

Total Transmission and Absorption Data of the Lens (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
300.0	<0.20	>2.699	>19.42	>8.43
320.0	9.00	1.046	7.52	3.27
340.0	2.00	1.699	12.23	5.31
360.0	0.50	2.301	16.56	7.19
380.0	1.50	1.824	13.12	5.70
400.0	14.00	0.854	6.14	2.67
420.0	63.50	0.197	1.42	0.62
440.0	90.00	0.046	0.33	0.14
460.0	93.00	0.032	0.23	0.10
480.0	93.50	0.029	0.21	0.09
500.0	94.00	0.027	0.19	0.08
550.0	95.00	0.022	0.16	0.07
600.0	95.00	0.022	0.16	0.07
650.0	95.50	0.020	0.14	0.06
700.0	96.00	0.018	0.13	0.06
750.0	96.00	0.018	0.13	0.06
800.0	96.00	0.018	0.13	0.06
850.0	96.00	0.018	0.13	0.06
900.0	95.50	0.020	0.14	0.06

Table XIX: (cont.)

Total Transmission and Absorption Data of the Lens (1967 Human Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
950.0	90.00	0.046	0.33	0.14
980.0	83.00	0.081	0.58	0.25
1000.0	86.00	0.066	0.47	0.20
1100.0	92.00	0.036	0.26	0.11
1200.0	66.50	0.177	1.27	0.55
1300.0	69.50	0.158	1.14	0.49
1400.0	4.00	1.398	10.06	4.37
1445.0	<0.20	>2.699	>19.42	>8.43
1500.0	0.50	2.301	16.56	7.19
1600.0	14.50	0.839	6.03	2.62
1700.0	15.50	0.810	5.83	2.53
1800.0	6.50	1.187	8.54	3.71
1900.0	<0.20	>2.699	>19.42	>8.43

Table XX

Direct Transmission and Absorption Data of the Cornea (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
280.0	<0.20	>2.699	>120.44	>52.31
300.0	10.00	1.000	44.62	19.38
320.0	34.00	0.469	20.91	9.08
340.0	45.00	0.347	15.47	6.72
360.0	51.50	0.288	12.86	5.59
380.0	54.00	0.268	11.94	5.19
400.0	57.50	0.240	10.72	4.66
420.0	60.50	0.218	9.74	4.23
440.0	63.00	0.201	8.95	3.89
460.0	65.00	0.187	8.35	3.63
480.0	67.00	0.174	7.76	3.37
500.0	69.00	0.161	7.19	3.12
550.0	73.50	0.134	5.97	2.59
600.0	77.00	0.114	5.07	2.20
650.0	79.00	0.102	4.57	1.98
700.0	81.00	0.092	4.08	1.77
750.0	82.50	0.084	3.73	1.62
800.0	84.00	0.076	3.38	1.47
850.0	85.00	0.071	3.15	1.37

Table XX: (Cont.)

Direct Transmission and Absorption Data of the Cornea (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
900.0	86.00	0.066	2.92	1.27
950.0	86.00	0.066	2.92	1.27
980.0	85.50	0.068	3.04	1.32
1000.0	85.50	0.068	3.04	1.32
1100.0	87.00	0.060	2.70	1.17
1200.0	86.00	0.066	2.92	1.27
1300.0	83.50	0.078	3.49	1.52
1400.0	38.00	0.420	18.75	8.14
1445.0	20.00	0.699	31.19	13.55
1500.0	38.00	0.420	18.75	8.14
1600.0	66.50	0.177	7.91	3.43
1700.0	66.50	0.177	7.91	3.43
1800.0	58.00	0.237	10.56	4.58
1900.0	0.50	2.301	102.68	44.59
1950.0	0.50	2.301	102.68	44.59
2000.0	2.00	1.699	75.81	32.93
2100.0	22.50	0.648	28.91	12.55
2200.0	32.00	0.495	22.08	9.59
2300.0	23.00	0.638	28.48	12.37

Table XX: (cont.)

Direct Transmission and Absorption Data of the Cornea (19[illegible]7 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
2400.0	16.50	0.783	34.92	15.17
2500.0	0.50	2.301	102.68	44.59

Table XXI

Total Transmission of the Cornea (1967 Monkey Data)

LAMBDA	% TRANS	ABSORBANCE	ALPHA	ABSORPTIVITY
280.0	<0.20	>2.699	>120.44	>52.31
300.0	16.00	0.796	35.52	15.[illegible]
320.0	54.00	0.268	11.94	5.19
340.0	67.50	0.171	7.62	3.31
360.0	74.00	0.131	5.84	2.53
380.0	80.00	0.097	4.32	1.88
400.0	83.50	0.078	3.49	1.52
420.0	86.00	0.066	2.92	1.27
440.0	88.00	0.056	2.48	1.08
460.0	90.00	0.046	2.04	0.89
480.0	91.00	0.041	1.83	0.79
500.0	91.50	0.039	1.72	0.75
550.0	92.50	0.034	1.51	0.66
600.0	94.00	0.027	1.20	0.52
650.0	94.50	0.025	1.10	0.48
700.0	95.00	0.022	0.99	0.43
750.0	95.00	0.022	0.99	0.43

Table XXII

Transmission and Absorption Data of the Aqueous (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
200.0	<0.20	>2.699	>23.90	>10.38
220.0	0.20	2.699	23.90	10.38
240.0	2.50	1.602	14.19	6.16
260.0	1.50	1.824	16.15	7.02
280.0	2.00	1.699	15.05	6.53
300.0	40.00	0.398	3.52	1.53
320.0	70.00	0.155	1.37	0.60
340.0	80.00	0.097	0.86	0.37
360.0	84.00	0.076	0.67	0.29
380.0	87.50	0.058	0.51	0.22
400.0	89.50	0.048	0.43	0.19
420.0	91.50	0.039	0.34	0.15
440.0	93.00	0.032	0.28	0.12
460.0	93.50	0.029	0.26	0.11
480.0	94.50	0.025	0.22	0.09
500.0	95.00	0.022	0.20	0.09
550.0	96.50	0.015	0.14	0.06
600.0	97.50	0.011	0.10	0.04
650.0	97.50	0.011	0.10	0.04

Table XXII: (cont.)

Transmission and Absorption Data of the Aqueous (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
700.0	97.[illegible]	0.011	0.10	0.04
750.0	98.00	0.009	0.08	0.03
800.0	98.00	0.009	0.08	0.03
850.0	97.50	0.011	0.10	0.04
900.0	97.00	0.013	0.12	0.05
950.0	95.00	0.022	0.20	0.09
980.0	90.50	0.043	0.38	0.17
1000.0	88.00	0.056	0.49	0.21
1100.0	90.50	0.043	0.38	0.17
1200.0	70.50	0.152	1.34	0.58
1300.0	65.00	0.187	1.66	0.72
1400.0	0.50	2.301	20.38	8.85
1445.0	<0.20	>2.699	>23.90	>10.38
1500.0	0.50	2.301	20.38	8.85
1600.0	12.50	0.903	8.00	3.47
1700.0	19.00	0.721	6.39	2.77
1800.0	7.00	1.155	10.23	4.44
1900.0	<0.20	>2.699	>23.90	>10.38

Table XXIII

Direct Transmission and Absorption Data of the Lens (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
300.0	<0.20	>2.699	>22.20	>9.64
320.0	5.00	1.301	10.70	4.65
340.0	1.00	2.000	16.45	7.14
360.0	0.50	2.301	18.92	8.22
380.0	0.50	2.301	18.92	8.22
400.0	2.00	1.699	13.97	6.07
420.0	35.00	0.456	3.75	1.63
440.0	71.00	0.149	1.22	0.53
460.0	82.00	0.086	0.71	0.31
480.0	84.50	0.073	0.60	0.26
500.0	86.50	0.063	0.52	0.22
550.0	87.50	0.058	0.48	0.21
600.0	89.00	0.051	0.42	0.18
650.0	89.50	0.048	0.40	0.17
700.0	90.00	0.046	0.38	0.16
750.0	90.50	0.043	0.36	0.15
800.0	90.50	0.043	0.36	0.15
850.0	91.00	0.041	0.34	0.15
900.0	91.00	0.041	0.34	0.15

Table XXIII: (cont.)

Direct Transmission and Absorption Data of the Lens (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
950.0	89.00	0.051	0.42	0.18
980.0	83.00	0.081	0.67	0.29
1000.0	85.50	0.066	0.56	0.24
1100.0	88.00	0.056	0.46	0.20
1200.0	68.50	0.164	1.35	0.59
1300.0	70.00	0.155	1.27	0.55
1400.0	5.00	1.301	10.70	4.65
1445.0	<0.20	>2.699	>22.20	>9.64
1500.0	0.50	2.301	18.92	8.22
1600.0	16.50	0.783	6.44	2.79
1700.0	18.50	0.733	6.03	2.62
1800.0	9.50	1.022	8.41	3.65
1900.0	<0.20	>2.699	>22.20	>9.64

Table XXIV

Total Transmission and Absorption Data of the Lens (1967 Monkey Data)

LAMBDA	% TRAN	ABSORBANCE	ALPHA	ABSORPTIVITY
300.0	0.50	2.301	18.92	8.22
320.0	9.00	1.046	8.60	3.73
340.0	3.00	1.523	12.52	5.44
360.0	1.00	2.000	16.45	7.14
380.0	1.00	2.000	16.45	7.14
400.0	10.00	1.000	8.22	3.57
420.0	62.00	0.208	1.71	0.74
440.0	90.50	0.043	0.36	0.15
460.0	93.00	0.032	0.26	0.11
480.0	95.50	0.020	0.16	0.07
500.0	96.50	0.015	0.13	0.06
550.0	97.50	0.011	0.09	0.04
600.0	97.50	0.011	0.09	0.04
650.0	98.00	0.009	0.07	0.03
700.0	98.00	0.009	0.07	0.03